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UNDERGROUND NUCLEAR EXPLOSIONS AT AZGIR, KAZAKHSTAN, AND IMPLICATIONS FOR IDENTIFYING DECOUPLED NUCLEAR TESTING IN SALT

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Bodywave magnitudes, m_b are recomputed for 17 nuclear explosions with yields of about 0.01 to 100 kilotons (kt) at Azgir in western Kazakhstan. Station corrections were developed for Azgir using larger events and then applied in recomputing magnitude of other explosions. Revised values of m_b for three tamped (fully coupled) explosions in salt at Azgir and one at Orenburg of announced yield, Y, were used to obtain the relationship, $m_b = 4.425 + 0.832 \log Y$. Salt is one of the best coupling geological media for generating seismic waves from underground nuclear explosions. In a special study made of the Azgir explosion of 1.1 kt of 1966 m_b was determined for 16 stations as $4.52 \pm .06$. For purposes of appreciating the detection capability of a given seismic network, it is important to recognize that a fully-coupled explosion of 1 kt in salt in high-Q (low attenuation) areas of the Former Soviet Union (FSU), like Azgir, has an m_b of 4.4; fully decoupled events of 1 and 10 kt have m_b's of about 2.6 and 3.4. Most areas of thick salt deposits in the C.I.S. are typified by high Q for P waves and low natural seismic activity.

Yields of all known nuclear explosions at Azgir and in other areas of thick salt deposits in the C.I.S. through May 1993 are recalculated. The yields of fully decoupled nuclear explosions of $Y \geq 0.5$ kt that possibly could be detonated in the cavities produced by those events are calculated.

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Nearly all of those cavities are situated in the area of extensive salt domes to the north of the Caspian Sea in the Pre-Caspian depression. The largest fully decoupled tests, up to a maximum of 4 kt, that could be conducted in cavities crated by past nuclear explosions are largely confined to Azgir itself. An important consideration in identifying cavities in salt created by past nuclear explosions is that the yield of a fully decoupled explosion in them cannot be larger than 5% of that of the explosion that created the cavity. The monitoring of fully decoupled explosions of $Y \geq 0.5$ kt set off in cavities created by past nuclear explosions would be a relatively easy task since the number of sites at which suitable cavities were created is quite limited. The FSU also conducted six very small nuclear explosions in a water-filled cavity at Azgir created by the 1968 explosion of 25 kt. Those six events, however, are all examples of enhanced seismic coupling at certain frequencies rather than of decoupled testing.

Ten tamped nuclear explosions at Azgir were relocated using seismic data and the locations of shot points on a SPOT satellite image taken in 1988. Most of the shot points are easily recognized on the image even though testing occurred there 9 to 22 years earlier. Since the Azgir area, like much of the Pre-Caspian depression, is arid, it would not be a suitable place for constructing large cavities in salt by solution mining and then using them for clandestine decoupled nuclear testing. A catalog (in Russian) of seismic readings from standard stations of the FSU for the 10 tamped explosions at Azgir was provided to us by Russian scientists and is reproduced in this report.

CONTENTS

INTRODUCTION

This paper examines the yields of past nuclear explosions at the Azgir testing area in western Kazakhstan and the yields of other nuclear explosions detonated by the Former Soviet Union (FSU) in or near other thick deposits of salt. Azgir, an area of low population density, which is underlain by salt domes of the Pre-Caspian depression, appears to have been a major testing ground for the technology and effects of peaceful nuclear explosions (PNEs) from 1966 through 1979. Nuclear explosions were also conducted at that site in the cavities created by larger nuclear explosions (Adushkin et al., 1993).

For the Azgir site where nuclear explosions of a variety of sizes from about 1 to 100 kt were conducted in salt (Adushkin et al., 1993), major emphasis is given to developing an m_b-yield relationship for salt for yields of 1 to 100 kt, calculating yields of past nuclear explosions in salt both at that site and elsewhere in the FSU, and assessing the potential for using large cavities that may remain from those explosions for future clandestine nuclear testing. A future paper will examine past nuclear explosions detonated in large cavities at Azgir in more detail than is done here, the numbers of chemical explosions in that area of comparable size to that of decoupled nuclear explosions, and the potential for conducting and identifying decoupled nuclear explosions of various sizes in other geological media.

In previous work my colleagues and I determined yields for Soviet explosions by using calibration curves for P waves that were based on underground explosions of announced yield for which their P-wave magnitudes were corrected for m_b bias between the actual test site of the explosion and the Soviet site in question. Sykes (1992) estimated the yields of underground explosions at the Shagan River (Balapan) testing area in eastern Kazakhstan using refined magnitude-yield relationships for both body and Lg waves. This paper seeks to further improve magnitude-yield relationships for nuclear explosions detonated in salt.

The detonation of nuclear explosions in large underground cavities under either a Low-Yield Threshold Test Ban Treaty (LYTTBT) or a Comprehensive Test Ban Treaty (CTBT) would constitute the greatest challenge to verification efforts. That evasion scenario sets the limit on how low a yield can be verified effectively. The OTA Report, *Seismic Verification of Nuclear Testing Treaties* (Office of Technology Assessment, 1988), focused upon the Soviet Union and concluded that between

1 to 2 and 10 kt the only plausible method of evasion is that of nuclear testing in large cavities in salt domes. It also concluded that no method of evading a good monitoring network is credible above 10 kt but that several evasion scenarios, including testing in cavities in bedded salt and in hard rocks, are possible below 1 to 2 kt. Much of my present efforts in nuclear verification are focused upon what I believe is the critical yield regime from 1 to 10 kt, where scientific research over the near term (a few years) seems most likely to have a major impact on the verifiability of either a LYTTBT or a CTBT and on what threshold can be verified effectively, e.g. 1, 3, 10 kt.

The idea that the seismic waves from underground nuclear explosions detonated in large underground cavities could be considerably reduced in size, i. e. decoupled, compared to the those from a tamped explosion was first proposed in 1959 (Latter et al., 1961). A tamped explosion is one where there are insignificant void spaces between the nuclear device and the surrounding rock medium, and a fully decoupled event is one where there is a large enough void space between the device and the surrounding material that no damage is done to the surrounding material (Denny and Goodman, 1990). The general concept of decoupling was confirmed in the Cowboy experiments where small (less than one metric ton) chemical explosions were set off in cavities excavated in a salt dome in Louisiana (Herbst et al., 1961). The United States has detonated only three nuclear explosions in salt. The first two, Gnome in New Mexico in 1962 with a yield of 3.4 kt and Salmon in Mississippi in 1964 of 5.3 kt (Rawson et al., 1966) were tamped events. Both of those explosions produced cavities that remained standing for many years, a situation that is almost unique to salt as a geologic testing medium. Cavities produced by tamped nuclear explosions in the common testing medium at the Nevada Test Site (NTS), tuff (Stevens et al., 1991), and in hard rock nearly always collapse in a relatively short time. Such cavities, of course, are not then available for use in conducting decoupled explosions.

The Sterling nuclear explosion, a decoupled event of 0.38 kt, was detonated in the Salmon cavity at a depth of 828 m in 1966 to test the decoupling concept (Springer et al., 1968; Healey et al., 1971; Denny and Goodman, 1990). It is the only decoupled U.S. nuclear explosion detonated in domed or bedded salt. Its small size, however, has resulted in a long controversy about the feasibility of conducting larger-yield, clandestine nuclear explosions in much larger cavities in salt and whether such events would be identified or not. Since Gnome and Salmon were both detonated prior to the installation of many high-gain short-period seismic stations and seismic arrays at teleseismic distances, a long debate has ensued about their bodywave magnitudes, m_b, and about m_b-yield relationships for tamped and decoupled nuclear explosions in salt.

Unlike the United States, the Former Soviet Union detonated a large number of nuclear explosions in and near thick deposits of salt, including a series of large underground explosions near the town of Azgir in western Kazakhstan and a series of nuclear explosions with yields of about 3 to 15 kt near Astrakhan in the adjacent part of the Russian Republic (Fig. 1). Azgir is located to the north of the Caspian Sea within the Pre-Caspian depression, which contains the world's largest concentrations of salt domes. Several other nuclear explosions were detonated by the U.S.S.R. from 1965 to 1988 in or near salt deposits (Sykes and Ruggi, 1989). Recently released information by the Russians on their program of nuclear explosions conducted in cavities at Azgir (Adushkin et al., 1993) indicates that a decoupled test of 8 kt was detonated in March 1976 within the air-filled cavity created in a salt dome by a tamped nuclear explosion eight times larger. The 1976 event was 20 times larger than the Sterling event and was recorded not only at local distances, like Sterling, but also at regional and teleseismic distances.

Clearly, there is much to be gained in understanding magnitude-yield relationships for nuclear explosions in salt and the feasibility of conducting and identifying clandestine decoupled explosions with yields from 1 to 10 kt by examining data from the much greater number of past Soviet explosions in salt and in urging the release of additional data on events of that type by the Russian Republic. There is no indication, however, that either the United States, the Soviet Union or the C.I.S. has created and evacuated a large solution-mined cavity and used it to test decoupled nuclear explosions.

Several important aspects of decoupling have received little study for more than 20 to 25 years. Since then a great deal of experience has been obtained by the U.S. and several European countries on the rheological properties of salt in conjunction with research on radioactive waste disposal in salt deposits and by industry on the construction and stability of large cavities in salt for petroleum storage and waste disposal. Experience with very large cavities in salt domes is now available from the U.S. Strategic Petroleum Reserve and from Europe, the C.I.S. and other parts of the U.S. on cavities created in salt for gas storage and on their stablility (or lack thereof). In addition yields, depths and cavity dimensions of explosions in salt at Azgir in 1966, 1968 and 1971 and at Orenburg in 1971 have been published (Kedrovskiy, 1970; Izrael' and Grechushkina, 1978; Adushkin et al., 1993) as have the yields, depths and rock types for a number of underground nuclear explosions at the eastern Kazakhstan test site (Bocharov et al., 1989). Thus, the time appears to be ripe for a reassessment of the feasibility of conducting decoupled nuclear tests of various sizes in large cavities in salt domes and ascertaining whether or not such events would be identified by various monitoring techniques.

BODYWAVE MAGNITUDES

Revised m_b values were recomputed for all known Soviet underground nuclear explosions in the vicinity of Azgir for which data were available from the International Seismological Center (ISC), the U. S. Geological Survey (USGS) and the Norsar and Hagfors seismic arrays in Scandinavia for the period January 1961 through May 1993. Station corrections for Azgir events were derived for seven large explosions at that site and then applied to all known underground events for that testing area. Similar previous work on magnitude and yield determination are described in Sykes and Ruggi (1986, 1989), Sykes and Ekstrom (1989) and Sykes (1992). Stations used in the recalculations were confined to the distance range 25° to 95°. A major object in this study was to reduce the standard error of the mean (SEM) for m_b to values as small as 0.015 to 0.03 by both using large numbers of stations (40 to 70 for larger events) and applying station corrections, i.e. making a correction for systematic differences in magnitude at individual stations for a given testing area. Since individual stations typically record explosions from a given test site with amplitudes that are consistently either higher or lower than the mean for each explosion, the application of station corrections considerably reduces the standard deviation of individual readings and avoids biases related to the inclusion or exclusion of individual readings from one event to another. It is particularly important to use station corrections since measurements of m_b from the stations of countries like Canada or France that operate large networks were not available for some explosions but were available for others.

Recomputed magnitudes for Azgir explosions, their SEM, and other pertinent data are listed in Table 1. As described later, the recalculations of m_b for the Azgir site do not represent maximum-likelihood determinations in which allowance is made for non-detection at additional stations (Ringdal, 1976). Instead, I emphasize the application of station corrections obtained from relatively large events to the determination of magnitudes of smaller events within the same testing area.

Small Azgir Explosion of 1966 and 25 kt Event of 1968

A special study was made of the Azgir explosion of 1.1 kt of 1966 wherein all available WWSSN and Canadian records were searched for the P wave from the event. m_b was measured at 16 stations, giving an average $m_b = 4.524 \pm .056$. (The uncertainty in magnitude as used here and throughout this paper is plus or minus one SEM.) Although small in amplitude, P waves could be readily identified at many of the better WWSSN stations of higher gain and good signal-to-noise ratio. The ability to detect such a small event 27 years ago using analog records from mainly simple (non-array) stations reflects the high coupling of a tamped underground explosion in salt and the efficent propagation (high Q) for P waves from the Azgir area to stations worldwide A similar study for the 1968 Azgir PNE event of 25 kt gave $m_b = 5.529 \pm .027$. For both of the two Azgir events, readings were used from only from those stations for which a station correction was available based on the seven large events at Azgir. This use of station corrections avoids the largest contributor to biased determinations of m_b for small events, i.e. the inclusion of raw m_b values that are mostly from stations that systematically report larger than average magnitudes, such as those in Scandinavia. For example, for the seven large Azgir events used in calculating station corrections, m_b values for Norsar are on the average 0.48 units larger than the event means. Correction for that systematic effect results in subtracting a station correction of 0.48 ± 0.08 from Norsar's raw m_b's.

MAGNITUDE-YIELD RELATIONSHIP FOR TAMPED NUCLEAR EXPLOSIONS AT AZGIR

The revised values of m_b and the published yields for the Azgir explosions of 1966, 1968 and 1971 and the Orenburg event of 1971, all of which are reported as having been detonated in salt, were used to obtain the m_b-yield relationship

$$m_b = 4.4250 + 0.832 \log Y. \qquad (1)$$

The yields of the explosions at Azgir in 1966 and 1968 were made public more than 23 years ago (Kedrovskiy, 1970) as part of an exchange of data on peaceful uses of nuclear explosions. The 64 kt yield of the Azgir explosion of 1971 is from Adushkin et al. (1993); the 15 kt value for the 1971 Orenburg event is from Nordyke (1975), Izrael' and Grechushkina (1978) and Borg (1984). The three tamped explosions in salt at Azgir have magnitudes similar to those of explosions of similar yield in hard rock in the southwestern portion of the Shagan River testing area in Central Asia (Fig. 2) and, once corrected for test site bias, to those of the three U.S. explosions of announced yield in granite in Nevada (Sykes, 1992). Thus, the Azgir events in salt exhibit a coupling of explosion energy into seismic wave energy that is about as efficient as that of explosions in granite and other hard rock.

MAGNITUDES OF TAMPED EXPLOSIONS IN SALT IN HIGH Q AREAS

Magnitudes of Salmon, Gnome and Small Events at Azgir

Even though the United States carried out its few (two tamped and one decoupled) nuclear explosions in salt more than 27 years ago, there has still not developed a consensus (at least in the U.S.) about the magnitudes of those explosions and about m_b-yield relationships for coupled and decoupled nuclear explosions for areas of thick salt deposits of the C.I.S. Those relationships are, of course, very important to considerations of the yields of decoupled nuclear explosions that might be tested clandestinely under either a LYTTBT or CTBT. Most of the early magnitudes published for those U.S. explosions rely mainly on measurements at distances less than 20^0 to 25^0 where amplitudes of P waves vary considerably from one region to another. For that reason most work on magnitude-yield relations since about 1968 has used data only from teleseismic distances, i.e. $\Delta > 20^0$ to 25^0. The SIPRI Seismic Study Group (1968, p. 101) pointed out that truly teleseismic data published for the Salmon event give a magnitude of 4.8 to 4.9 whereas the inclusion of data from closer distances leads to lower estimates.

Some workers have argued that the use of teleseismic arrivals from Salmon leads to overestimates of its m_b since those data come only from stations with relatively high signal levels. Since larger explosions were not conducted at the Gnome and Salmon sites, they cannot be used to develop station corrections that could be applied to those relatively small explosions as I have done for the much greater number and size range of nuclear explosions in salt at Azgir or has been done for major test sites like NTS and Shagan River. The SIPRI Seismic Study Group (1968, p. 102), referring to a presentation by Peter Marshall, points out that stations with a gain of at least

100 K would be needed to detect an event the size of Salmon at teleseismic distances. That study states: "When Jordan et al.'s [1966] stations are examined, it is found that of 10 stations with gains greater than or equal to 100 K, 9 reported an observation." "Values from these averaged to 4.9." The SIPRI study goes on to conclude (p. 102) "There seems therefore a good case for SALMON having a magnitude of between 4.75 and 5.0." Marshall et al. (1979) calculated a magnitude and SEM for Salmon of 4.87 ± 0.08 using data from 11 stations at $\Delta > 20^{o}$. When that m_b value is corrected for the relative attenuation between the Salmon and Azgir testing areas using the data and formulas of Der et al. (1985), $m_b = 4.90$ is obtained. Using that m_b, a yield of 3.7 kt is derived from equation (1), which is only somewhat smaller than the announced yield of 5.3 kt. Thus, the calibration data from Azgir explosions are consistent with an m_b for Salmon near 4.9, i.e. in the range quoted by the SIPRI Seismic Study Group (1968).

Using a maximum likelihood program developed at Teledyne-Geotech (Blandford et al., 1984; R. R. Blandford, written communication to P. G. Richards, 1989) and Jih and Wagner (1991) obtained the following much smaller m_b values for Salmon: 4.31, 4.45 and 4.20 respectively. In his written communication Blandford states that he used 11 observations of m_b of Jordan et al. (1966) for $30^{o} < \Delta < 90^{o}$ as well as assumptions about the noise levels at many other stations in that distance range for which P waves were not observed by Jordan et al. It seems clear that Blandford's assumptions about noise levels in data read by others are crucial in his determination of m_b using the maximum likelihood procedure that seeks to deal with stations that do not observe an event as well as with those that do. Jih and Wagner (1991) used m_b values from 6 stations and measurement of noise at 33 others in the range $20^{o} < \Delta < 90^{o}$ in their determination.

The veracity of the Teledyne-Geotech procedures and estimates of m_b for Salmon now can be checked with information from Azgir. Jih and Wagner (1991) report m_b's (which they call Geotech's maximum-likelihood network m_b) of 4.225 ± 0.083, 5.542 ± 0.040 and 3.986 ± 0.073 for the Azgir events of 1966, 1968 and April 25, 1975 for which I estimated their m_b's to be 4.524, 5.529 (Table 1) and 4.45 ± 0.13 (Table 2). For the 1968 event of 25 kt they used 44 m_b values and 10 noise estimates whereas I used 20 values for which station corrections to m_b were available from seven large events at Azgir. My estimate, theirs, and that of Marshall et al. (1991) of m_b 5.57, which is also a maximum-likelihood determination, are statistically indistinguishable for the 1968 explosion. This is not surprising since each used relatively large numbers of m_b values in their determinations. Also, Ringdal found little or no difference between magnitude estimation techniques for $m_b \geq 5.0$.

For the 1966 event of 1.1 kt, however, Jih and Wagner used only three m_b values but included 10 noise observations whereas I used 16 readings, each of which incorporated a station correction. The situation is even more extreme for the 1975 explosion where Jih and Wagner used merely a *single* m_b value and 16 noise estimates whereas I used seven values of m_b, each of which incorporated a station correction. For the 1975 event their m_b estimate is 0.46 units smaller than mine. Marshall et al. (1991) obtained a maximum-likelihood m_b of 4.59 for the 1975 event, which is statistically indistinguishable from my value but is 0.60 m_b units larger than that of Jih and Wagner (1991).

Thus, for two of small Azgir events Jih and Wagner (1991) report considerably smaller magnitudes than those obtained by either Marshall et al. (1991) or me. Procedurally it seems that the Teledyne-Geotech m_b values for small events suffer from a reliance on a very few actual readings, lacking many data from standard sources like ISC, USGS, Norsar, Lasa, the Hagfors array in Sweden and WWSSN stations, as I used in obtaining my estimates. When the number of m_b measurements in the Geotech database is very small (3 and 1 for the 1966 and 1975 Azgir events) and the number of noise estimates is much larger, it seems clear that their calculated magnitudes and SEM's are systematically too small. Note that this should not be taken as a criticism of the maximum-likelihood technique itself since Marshall et al. (1991) obtained a similar result to mine for the 1975 explosion.

Returning to the Salmon event, it is clear that using just six m_b values and 33 estimates of noise as Jih and Wagner (1991) did, when at least 11 m_b values were available at distances greater than 20^o, probably also led to their very small estimates of m_b and its SEM for Salmon. Likewise, similar reasoning indicates that the m_b values of Blandford et al. (1984) and Blandford (written communication, 1989) are also too small.

Not much can be done in utilizing the data from the Gnome explosion since Marshall et al. (1979) report only two m_b readings for $\Delta > 20^o$, whose average is 4.13. If the poorly known site bias for the Gnome area with respect to Azgir is like that of NTS with respect to Azgir, 0.323 m_b units (Der et al., 1985), $m_b = 4.45$ is obtained for Gnome as normalized to Azgir. In view of the large uncertainty in the m_b determination for Gnome, however, the m_b values for explosions at Azgir appear to be more precise since they are not biased by either a lack of station corrections, an uncertain estimate of attenuation, or a very small number of P waves observed at teleseismic distances.

MAGNITUDE-YIELD RELATIONSHIPS FOR COUPLED AND DECOUPLED EXPLOSIONS IN SALT IN HIGH Q AREAS

Is Salt a High or Low Coupling Testing Medium?

Most workers who have studied the seismic waves from underground nuclear explosions in thick deposits of salt (e. g. SIPRI Seismic Study Group, 1968; Marshall et al., 1979; Rodean, 1981) have concluded that salt is one of the best-coupling, common geologic media, i. e. that tamped explosions of a given yield in salt have among the largest bodywave magnitudes compared to those for other testing media. The large values of m_b in Fig. 2 for the three Azgir explosions of published yield supports that contention. This is reasonable since salt has a low porosity, and relatively little of the energy of the explosion must be expended in closing pore space, especially air-filled pore space, as is the case with explosions conducted above the water table in less competent sedimentary rocks and alluvium.

Based on their determination of the m_b of Salmon, Blandford et al. (1984), however, conclude that its magnitude, when corrected for bias between testing areas, was 0.4 m_b units below the magnitude-yield curve for shots in volcanic and granitic rocks in Nevada, Amchitka and Algeria. They conclude from that single data point for Salmon that explosions in salt couple less well than those in the above hard rocks. In the light of my finding that their m_b is likely to be seriously underestimated for Salmon, however, there is no remaining rationale for concluding that tamped explosions in salt couple less well than those in granite and other hard rocks.

Magnitudes of 1 and 10 kt Nuclear Explosions in Salt in High-Q Areas

Eqn. (1), the magnitude-yield relationship derived earlier for tamped nuclear explosions in salt at Azgir and Orenburg, implies that a fully-coupled (tamped) nuclear explosions of 1 and 10 kt in salt in those and similar high-Q areas of the FSU have m_b's of 4.42 and 5.26 respectively. The OTA Report (Office of Technology Assessment, 1988) and a number of other investigators have concluded that the average decoupling factor (DF) at low frequencies for the Sterling nuclear explosion was about 70 times, i. e. the amount by which its seismic amplitude at low frequencies was reduced compared to that of a tamped explosion of the same yield at that location. Since the yield of Sterling, 0.38 kt, was somewhat larger than that calculated theoretically for full decoupling, 0.21 kt, some workers have maintained that somewhat higher decoupling factors would be expected for a mined cavity in salt of a size such that the salt surrounding the cavity remains wholly in the elastic regime. The OTA Report concluded, however, that the experience from Sterling and the re-analysis of the Cowboy data from chemical explosions in salt, which also gives a maximum DF of about 70 (Murphy, 1980), indicates that larger values of DF are unlikely to be achieved in practice. For purposes of calculating magnitudes of fully decoupled explosions I assume a DF of 70. Subtracting log 70 from (1), the following expression is obtained for fully decoupled explosions in salt at Azgir and other high-Q areas of the FSU:

$$m_b = 2.58 + 0.832 \log Y. \tag{2}$$

Assuming that attenuation of P waves leaving the high Q (efficient transmission) Azgir site is the same as that for other high-Q areas of the C.I.S., fully decoupled events of 1 and 10 kt would have m_b's of 2.58 and 3.41 respectively. Most areas of thick salt deposits in the former U.S.S.R. are typified by high Q for P waves and low natural seismic activity. These magnitudes are higher than has generally been thought previously for fully decoupled nuclear explosions. For example, Murphy et al. (1988) state "Cavity decoupled underground nuclear explosions in the yield range from 1 to 10 kt can be expected to generate seismic signals corresponding to m_b values in the 2.0 to 3.0 range . . ." One of the smallest magnitudes estimated is that of Werth and Randolph (1966) who concluded that a 5-kt, fully decoupled explosion would be down in amplitude from that of Salmon by a DF of 170 or a magnitude of 2.1. Eqn. (2) gives $m_b = 3.16$ for 5 kt fully decoupled, a full magnitude larger than their estimate. Their low estimate arises at least in part from using an m_b (4.35) for Salmon determined from stations as close as 16^0, data from a single pair of tamped and decoupled explosions, and too large a decoupling factor in the light of the re-evaluation of the data from the Cowboy set of chemical explosions.

CAPABILITIES OF SEISMIC NETWORKS FOR IDENTIFYING DECOUPLED NUCLEAR EXPLOSIONS IN C.I.S.

Figure 2 indicates the expected magnitudes of contained underground nuclear explosions of various yields in the territory of the former Soviet Union. The range of m_b's for tamped (fully coupled) events in hard rocks and water-saturated rocks is meant to cover the range of experience reported in the literature for differences in coupling near the shot point for those media as well as differences in the attenuation of P waves transmitted to teleseismic distances. Note that the line labelled SW Shagan River on Figure 2, which pertains to a hard rock site with low attenuation for P waves, falls near the top of that regime as do the data points for the three Azgir explosions in salt. Dry porous media (Fig. 2) do not appear to be present in sufficient thicknesses anywhere in the C.I.S. such that explosions could be detonated in them clandestinely with yields larger than 1 to 2 kt (SIPRI Seismic Study Group, 1968; Office of Technology Assessment, 1988). The upper limits of possible underground testing in Figure 2 are taken to be the present 150 kt limit of the TTBT for hard rocks and water saturated rocks and the upper limit of 10 kt for conducting clandestine testing in large cavities in salt domes as described in *Office* of Technology Assessment (1988).

The OTA Report described the *identification* threshold as of 1988 for the C.I.S. as m_b 4.0 (which is, of course higher than the *detection* threshold for seismic events). That assessment did not included data from stations within the FSU, such as that from the newer IRIS stations. At that capability, tamped explosions at Shagan River would be identified down to several tenths of a kiloton; some events in hard rock and water saturated rock in areas of low P-wave attenuation of the C.I.S. might go unidentified for yields as large as nearly 3 kt. The OTA Report concluded that at an identification threshold of 4.0 that fully decoupled explosions in salt domes might go unidentified for yields as large as 10 kt, a level largely set by the size of cavities that could be constructed and used clandestinely and the low levels of natural seismic activity for most salt domes areas of the Soviet Union.

Members of the panel that advised OTA on their 1988 study, of which I was a part, did not reach a consensus on what the identification threshold for the C.I.S. would be if data from a good internal seismic network were available in addition to data from external stations. There was agreement (p. 92) that "identification can be accomplished in the U.S.S.R. down to *at least* as low as m_b 3.5." The Report goes on to state "Many experts claim that this identification threshold is too cautious and that with an internal network, identification could be done with high confidence down to m_b 3.0." Figure 2 indicates that an identification capability of m_b 3.5 would include many events in the FSU down to about 0.07 kt, and events in all hard rocks and those below the water table down to 0.75 kt but might miss fully decoupled events as large as 10 kt. A capability to discriminate at m_b 3.0 would lead to the identification of fully decoupled events in salt domes down to yields of 2 to 4 kt.

The regime labelled "salt, fully decoupled" in Figure 2 pertains to high Q areas of the C.I.S, which includes most but not all salt domes. Salt domes in more seismically attenuating areas are concentrated in the Republic of Tadjakistan, which is now a separate country from the Russian Republic. A better identification capability for possible decoupled explosions in that area, if deemed necessary, could be furnished by a local seismic network. The major civil war that has been in progress in Tadjikistan for the last few years, however, would undoubedly make the conduct of nuclear tests of any kind in that area very difficult, if not impossible so long as the war continues. Likewise, it would likely limit or prohibit the operation of seismic stations in Tadjikistan.

Stevens et al. (1991a) and others imply that the C.I.S. could conduct clandestine nuclear explosions in other dry materials such as dry tuff, which is present in thick quantities at NTS. Dry tuff of significant thicknesses for even small nuclear tests appears to be present in the C.I.S. only in the Caucasus region. Again, a monitoring network in the vicinity of those deposits could provide better identification for that region if it were deemed necessary under a LYTTBT or CTBT. Conducting clandestine nuclear explosions in dry porous alluvium would be very risky for a potential evader since that material is very weak and undergoes significant compaction when nuclear explosions are fired in it. The collapse of the cavity formed by such an explosion, which is almost certain to occur, may well produce significant disturbance at the surface, even if it is overburied. This could readily be detected by satellite photography or air surveillance.

CAVITIES FORMED BY NUCLEAR EXPLOSIONS IN THICK SALT DEPOSITS OF C.I.S. THAT MIGHT BE USABLE FOR CLANDESTINE TESTING

Inventory of Past Nuclear Explosions of FSU in and near Thick Salt Deposits

The U.S.S.R. carried out a number of nuclear explosions in salt near Azgir and conducted several other PNEs in regions known to contain salt. Cavities produced by nuclear explosions in salt, such as Salmon and Gnome in the United States, have remained standing for many years whereas cavities produced in other rock types usually collapse within short periods of time. Many investigators evaluating the possibility of decoupled nuclear testing that might be conducted under either a CTBT or a LYTTBT have paid considerable attention to the potential use of cavities produced by nuclear explosions in salt. I will show, however, that monitoring of the relatively few areas of the C.I.S. in which cavities of that type could exist and could be used in the future for the full decoupling of explosions with yields larger than 0.5 kt is tractable, given both a problem-solving approach and the inclusion of reasonable verification measures in a treaty to further limit nuclear testing. Instead, more attention needs to be devoted to the feasibility of decoupled testing in the yield range from 1 to 10 kt in large cavities produced by solution mining. More potential sites are available in the C.I.S. for creating large cavities by solution mining than are available from past nuclear explosions in salt.

Table 1 lists underground nuclear explosions that were detonated by the FSU through June 1993 either in or near thick salt deposits. The latest events on that list were conducted in 1988. The judgment as to whether or not an explosion occurred in or near a thick salt deposits was largely based on its location with respect to the maps of salt deposits of Elias et al. (1966) and Rachlin (1985). Subsequent to writing the first draft of this paper Sultanov et al. (1993) published information on Soviet PNEs that includes the rock type at the hypocenter of the explosion. All of the events that they list as occurring in salt are shown in Table 1 without a designation as to rock type; all others that they report in other rock types are so designated in Table 1.

Nuclear explosions detonated in cavities at Azgir are not included in Table 1 but are listed separately in Table 2. As mentioned earlier, yields of tamped explosions at Azgir were determined using recalculated m_b values that included station corrections derived for that site. The explosions at Azgir listed in Table 1 have calculated yields between 1.3 and 93 kt. That range is in good agreement with the statement by

Adushkin et al. (1993) that tamped nuclear explosions at Azgir were in the yield range from 1 to 100 kt and the reported yield of 1.1 kt for the 1966 explosion. Those events occurred between April 1966 and October 1979 in the area of numerous salt domes to the north of the Caspian Sea. Applying station corrections determined from explosions at Azgir to events more than 100 km away, however, did not reduce the SEM of those m_b values. Hence, station corrections were not used in recomputing m_b for the other events in Table 1.

The yields, Y(mb), of all of the events in Table 1 were calculated from equation (1). It is assumed in those calculations that all of the events in Table 1 were tamped explosions and that all occurred in salt in areas of low attenuation for P waves transmitted to teleseismic distances. Announced yields are listed in a separate column. In Table 1 origin times and locations for events at Azgir are from Sykes et al. (1993); those of explosions at Astrakhan, Lake Aralsor, Orenburg and Karachaganak are from Marshall et al. (1991); the others are from the ISC bulletins.

Conservative Assumptions about Use of Cavities for Possible Clandestine Testing

I now estimate the maximum yields of fully decoupled nuclear explosions that could be detonated in cavities created by past Soviet nuclear explosions detonated either in or near thick salt deposits of the C.I.S. Two conservative assumptions are made in ascertaining potential sites where decoupled tests might be performed in the future. One is that all of the events in Table 1 occurred in thick deposits of salt. Sultanov et. al (1993) state that several of the events in Table 1, however, were detonated in either anhydrite, clay, or dolomite and not in salt. Those events are so annotated in Table 1. Without precise knowledge of the depths of explosions and details of the stratigraphy for regions of bedded salt, it is not possible to ascertain whether explosions, in fact, occurred in salt or in some other rock type. An example of this is the series of nuclear explosions (Table 1) that have been detonated south of the town of Mirnyy near 61.5°N, 112.8°E within the large region of bedded salt to the northwest of Lake Baikal. Sultanov et. al (1993) indicated that only one of those explosions occurred in salt; the others were conducted in dolomite in conjunction with oil recovery.

Other conservative assumptions are that cavities have remained standing for all of the events in Table 1 and that water present in any of them can be removed so that decoupled testing would be possible. Kedrovskiy (1970) mentions that the small cavity created by the 1966 explosion at Azgir filled with water. Russian scientists have stated that the larger cavity created by the nearby 1968 explosion filled with water and that six of the very small explosions in Table 2 were detonated in it. As discussed later, they are examples of enhanced coupling at frequencies of about 7 to 9 Hz. rather than decoupled tests.

Cavity Volume as a Function of Yield and Depth of Tamped Nuclear Explosions in Salt

Information about the depths and dimensions of the cavities created in salt by the U.S. explosions Salmon and Gnome, three explosions at Azgir and one near Orenburg are used to calculate yields of fully decoupled nuclear explosions that could be conducted in the cavities assumed to remain standing from the events in Table 1.

Salmon, a fully-tamped explosion of 5.3 kt, was detonated in a salt dome in the state of Mississippi at a depth of 828 m in 1964. The Sterling nuclear explosion, a decoupled event of 0.38 kt, was detonated in the Salmon cavity at the same depth in 1966 (Denny and Goodman, 1990). The Salmon cavity, like that produced by the Gnome explosion in bedded salt in New Mexico and those produced by the tamped Azgir explosions of 1966, 1968 and 1971 in salt domes, was not perfectly spherical in shape. In each case a significant amount of rubble, radioactive products and re-solidified salt accumulated at the bottom of what was initially a more nearly spherically shaped cavity. In the following descriptions and calculations the cavity volume, V_C , referred to is the remaining volume; it does not include the rubble zone since it is the remaining volume that is pertinent to the conduct of possibie decoupled nuclear tests in those cavities.

V_C for the Sterling event was 19,400 m^3, giving a mean radius of 16.7 m (Denny and Goodman, 1990). The Gnome explosion of 1962 was conducted in bedded salt at a depth of 361 m and produced a V_C 27,400 m^3 (Rawson et al, 1966). The 1968 Azgir event of 25 kt was detonated at a depth of 590 m and produced a cavity with a volume of 140,000 m^3, giving a mean radius of 32.2 m (Kedrovskiy, 1970). The Soviet explosion at Orenburg of October 22, 1971 of 15 kt in bedded salt was used to produce a cavity for storing gas condensates at depth of 1140 m. Its volume was 50,000 m^3, giving a mean radius of 22.9 m (Nordyke, 1975; Izrael' and Grechushkina, 1978; Borg, 1984). The 1971 Azgir explosion of 64 kt was detonated at a depth of 987 m and produced an air-filled cavity with a volume of about 214,000 m^3 (Adushkin et al, 1993) and a mean radius of 37 m. That cavity was used to conduct a partially decoupled nuclear explosion of 8 kt in 1976 (Adushkin et al, 1993). The 1966 Azgir explosion of 1.1 kt was detonated at a depth of about 165 m and generated a cavity with a volume of 10,000 m^3 (mean radius of 13.4 m).

Containment Criteria for Fully Decoupled Nuclear Explosions

The minimum depth for a clandestine test in an underground cavity in salt is determined by the requirement that the explosion not produce a crater or other disturbance at the surface and that it be fully contained so as not to leak radioactive products to the surface. For a very weak material like salt, Latter et al. (1961) conclude that the amplitude of the long-term step of pressure on the cavity wall for full decoupling must be less than or equal to one half of the overburden pressure (i.e. half of the vertical stress, ρgh) so as to prevent failure in tension of the surrounding salt material and, hence, to prevent leakage of radioactive gases from the cavity. Since salt, like other geological materials is very weak in tension, the presence of a compressive overburden stress is need to make sure that salt near the cavity wall is not subjected to tensional stress by the pressure step from the explosion. The relationship between a step in cavity pressure, P, produced by a decoupled explosion of yield, Y_D, in a cavity of volume, V_C , and the requirement for containment that P be less than some constant, k, times the vertical stress can be written

$$P = (\gamma-1)Y_D/V_C \leq k\,\rho gh \qquad (3)$$

where γ is the ratio of heat capacity at constant pressure to that at constant volume, which is taken to be 1.2 for an air-filled cavity (Latter et al., 1961), ρ is the average density of the material from the surface to the depth, h, of the cavity and g is the gravitational acceleration at the earth's surface. The average density in the following applications is taken to be that of salt at the Salmon site, 2200 kg / m^3 (Stevens et al., 1991), similar to that reported for Azgir (Kedrovskiy, 1970; Adushkin et al., 1993). For the Latter criterion mentioned above, k = 0.5.

Maximum Fully Decoupled Yields Possible for Various Cavities

Taking the relevant parameters for the cavities created by the Salmon, Orenburg and the 1966, 1968 and 1971 Azgir explosions, the maximum yields of fully decoupled explosions according to the Latter criterion that could be detonated in those cavities (after converting the energy in Joules, J, to kilotons, where 1 kt = 4.184 x 10^{12} J) are 0.21, 0.75, 0.02, 1.1 and 2.7 kt respectively (Table 1). The ratio, Y_{FD}/Y, of the yield of the largest fully decoupled event that could be detonated in each of those cavities to the yield of the tamped nuclear explosion that was used to create those cavities is 1/26, 1/20.4, 1/53, 1/24 and 1/24 for the above five events respectively (Figure 3). For the other events in Table 1 for which information on yield, cavity dimensions and depth have not been published, the maximum yield of a fully decoupled explosion, Y_{FD}, that could be detonated in the cavities created by those events was obtained by multiplying the announced or calculated yield, Y, in Table 1 by 1/20, the largest ratio obtained for the above five events. Values of Y_{FD} are listed in Table 1 if they are greater than or equal to 0.5 kt.

It should be appreciated that fully decoupled and partially decoupled nuclear explosions larger than 1 kt would have to be conducted within a fairly narrow range of depths. An air-filled cavity in salt is likely to deform significantly at depths greater than about 1000 to 1200 m. In fact, it is questionable whether the cavity produced by the Orenburg explosion of 1971 at a depth of 1140 m could be safely evacuated for clandestine testing without it deforming significantly. Since it was intended for storage of gas condensates, the presence of that material in the cavity provides a significant amount of the support for the cavity, allowing it to remain relatively undeformed to a greater depth than would be the case of an air-filled cavity at atmospheric or lower pressures. Russian scientists have stated that several of the cavities created by nuclear explosions in salt at a depth of about 1100 m in the Pre-Caspian depression have either collapsed or suffered enough of a reduction in volume that they could not be used for their intended industrial use, storage of gas condensates. Filmmakers for a National Geographical Society film on the Volga River interviewed health professionals in Astrakhan. They were informed that 13 of the 15 cavities created by nuclear explosions (Table 1) near Astrakhan (Fig. 1) experienced those problems.

Not much purpose is served, however, by debating whether the maximum depth of a stable air-filled cavity in salt is say 1000 or 1200 m. That depth varies from place to place and is dependent upon the temperature gradient, amounts of other evaporite minerals present in addition to NaCl, grain size, and the presence or absence of inclusions of salt brine (Jenyon, 1986). The main point is that cavity stability cannot be insured except at quite shallow depths in the crust, depths shallower than those of many salt bodies and depths much shallower than those of many oil and gas wells. For example, a salt deposit at a depth of say 5 km cannot be used to create a large cavity. Likewise, an evader determined not to be caught testing at such yields, would use only cavities that are at least several hundred meters deep to insure containment and to prevent bomb-produced products from escaping from the cavity.

Figure 3 shows the scaled cavity volume, V_C/Y, as a function of depth for tamped explosions in salt of published yield. V_C/Y clearly decreases with depth. There is a tradeoff, however, between the fact that a shallower tamped explosion produces a larger cavity than a deeper one in the same material and the fact that a larger cavity at a shallower depth is needed to satisfy inequality (3) for a decoupled event of yield, Y_D. As shown at the top of Figure 3, larger values of Y_{FD}/Y are obtained at deeper depths. That ratio, however, does not increase much between 360 and 1140 m.

The slow increase of Y_{FD}/Y with depth, h, at the top of Figure 3 can be understood as follows. The data in the lower half of Figure 3, not including that for the 1971 explosion, were best fit with regressions of form $V_C/Y \sim h^{-n}$. For the solid line, which includes the data point for the shallow small event of 1966, n = 0.57. When that data point is excluded (dashed line), n = 0.83. Given the yield of a tamped explosion, Y, and h eqn. (3) can be rewritten

$$Y_{FD} \leq k\rho g h V_c / (\gamma - 1) \sim Y h^{1-n} \tag{4}$$

where 1-n is 0.43 with and 0.17 without using data from the small, shallow event of 1966. Thus, for a given yield, Y, of a tamped explosion in salt, the yield, Y_{FD} of a fully decoupled explosion that can be detonated in its cavity, increases slowly with the depth of the tamped explosion.

Since the depths of most of the explosions in Table 1 are not known, assuming that they occurred at the depth of the deepest known nuclear explosion in salt in Figure 3 and taking the ratio of $Y_{FD}/Y = 1/20$ should lead to conservative estimates of Y_{FD}. Uncertainties in calculating the yields of the events in Table 1 can lead to uncertainties of a factor of 1.5 to 2.0 in Y_{FD}. My main concern here, however, is what are the possibilities that may be available to test weapons clandestinely of certain approximate sizes.

Sterling was almost, but not fully decoupled; P was a factor of 1.8 = 0.38 / 0.21 times larger than that calculated for full decoupling by the Latter criterion. If Sterling conditions, i. e. k = 0.90, apply rather than the Latter criterion, the decoupled yields in the last column of Table 1 should be multiplied by 1.8. The value k = 0.90 calculated for that event using equation (3) indicates, however, that P still did not exceed the vertical stress (k = 1). Experience with cavities in salt used for high-pressure gas storage indicates that leakage may occur when the internal pressure in the cavity exceeds the vertical stress (Berest and Minh, 1981). In fact, Latter (1960) was well aware of this "general rule of thumb" during the initial work on decoupling 33 years ago.

Thus, much larger (20 to 55 times larger) tamped explosions are needed to create cavities than the maximum sizes of fully decoupled explosions that can be detonated in them according to the Latter criterion (k=0.5). For Sterling conditions (k=0.9) that ratio is 12 to 31. This ratio is important since unclassified data alone are sufficient to identify down to a small yield all past Soviet and U.S. underground nuclear explosions that were detonated either in or near areas of thick salt deposits or in other areas that conceivably could be the sites of such deposits. The yields of fully decoupled explosions that could be detonated in cavities that may remain standing from those events according to the Latter criterion is at least a factor of 20 smaller than the yields of the explosions that generated those cavities. For Sterling conditions, the yield must be at least 12 times smaller.

Inventory of Cavities Suitable for Full Decoupling by Region and Yield

Table 3 summarizes the yields of fully decoupled nuclear explosions, $Y_{FD} \geq 0.5$ kt, that could by detonated in the cavities of events in Table 1 both by area and size. Most of the possibilities for such testing are concentrated in the area to the north of the Caspian Sea in the Pre-Caspian depression (Fig. 1). The possibilities for conducting larger tests, up to a maximum of 4.2 kt fully decoupled, are mostly confined to Azgir itself. Possibilities for decoupled testing in cavities created by past nuclear explosions within the area of bedded salt to the northwest of Lake Baikal are few and the yields very small. Sultanov et al. (1993) list only a single small nuclear explosion in salt in that area.

The Bukhara II event of May 1968 (Table 1) was used to put out a fire in a gas well, the drilling of which had encountered an unanticipated fault that had provided pathways for escaping petroleum (Kedrovskiy, 1970; Nordyke, 1975). It was detonated at a depth of 2440 m near the boundary between anhydrite and salt (Kedrovskiy, 1970; Nordyke, 1975). The great depth of the Bukhara II explosion insures that any cavity that may have been created undoubtedly closed soon after detonation, as, in fact, was the intention in putting out the gas fire. The presence of a fault known to have leaked in the past would make the conduct of a decoupled nuclear test at that site a risky proposition even if a cavity did remain standing.

The two explosions of 1972 in Table 1 to the northeast of Elista and at Lake Aralsor were situated along an 800-km long deep seismic sounding profile for which a cross section is reproduced in Scheimer and Borg (1984). The cross section indicates that salt is only present at a depth exceeding several kilometers for the first explosion and is absent altogether near the second. This is in accord with the statement of Sultanov et al. (1993) that the Lake Aralsor and Elista explosions were conducted in clay and with that by Bogacheva et al. (1965) that the 6800 m deep Aralsor borehole (which was located at or near the explosion) penetrated a complete Triassic sequence of rocks that are undisturbed by salt tectonics, i.e. by the presence of salt diapirism.

If the statements by Russian scientists about the events in Table 1 that were detonated in clay are correct, all of the cavities that may remain standing from past nuclear explosions in salt that could be used for full decoupling of explosions of Y $\geq$ 1 kt are situated at Azgir. If that is the case, the monitoring of such cavities by a combination of a local seismic network, satellite and air photography and on site inspections would be very easy if provisions to that effect are included in any test ban treaty. In any case, it would not be much more difficult in a monitoring program agreed to by treaty to include the sites of the other past large nuclear explosions in Table 3 for which the events are reported to have been detonated in clay.

Thus, the number of cavities produced by past nuclear explosions in the C.I.S. that potentially could be used for clandestine testing of fully or nearly fully decoupled nuclear explosions under either a CTBT or a LYTTBT is very limited. Those sites are confined to a few areas of the former U.S.S.R. Most, and perhaps all, of the larger cavities produced by nuclear explosions that may remain standing are situated in the Republic of Kazakhstan and not in the Russian Republic. One small nuclear explosion in salt with a yield of about 3 kt (Table 1) was detonated in the Ukraine (Sultanov et al., 1993).

The question of using cavities created by past nuclear explosions for partially decoupled events as described by Stevens et al. (1991) will be dealt with in a separate paper along with the feasibility of constructing and using cavities in hard rock for either the full or the partial decoupling of explosions with yields from 1 to 10 kt.

NUCLEAR EXPLOSIONS DETONATED IN A WATER-FILLED CAVITY AT AZGIR

The Norsar and Hagfors arrays and the ISC Bulletin have each located a number of small events in the general vicinity of Azgir, including the partially decoupled explosion of 1976. Sykes and Lyubomirskiy (1992) made a special study of small events reported by the ISC, Norsar and Lasa in the 5^0 by 5^0 box outlined in Figure 2 that includes Azgir and Astrakhan for the 23-year period 1969 through 1991. They compiled a catalog of chemical and nuclear explosions in that region that they show is complete down to m_b 3.1 since 1969. That m_b corresponds to a tamped nuclear explosion of about 0.025 kt and to yields of about 1 and 4 kt for decoupling factors of 20 and 70. This capability was made possible by recognizing that the Norsar, Hagfors and Lasa arrays recorded seismic waves from large events at Azgir that have m_b's about 0.5 units larger than the average. Thus, those arrays have (or for Lasa had) a detection capability for Azgir that extends down to a very small m_b and yield. The location capability of those arrays by themselves, however, is poor compared with that of either a local seismic network or data from several arrays well distributed in azimuth. Either of those can be obtained by the installation of appropriate seismic monitoring equipment.

Sykes and Lyubomirskiy (1992) reported that seven small events of m_b 3.02 to 4.45 from their catalog fulfill an origin-time criterion (being detonated exactly on the hour within the uncertainty in estimating origin time) for being either very small tamped or small decoupled nuclear explosions, one of which is the 8-kt partially decoupled event of 1976. Of the 126 other small events in the area, most or all of which are taken to be chemical explosions from their concentration during the work day, the largest two in 23 years were of m_b 4.0. Chemical explosions of $m_b \geq 3.5$ and those of $m_b \geq 3.0$ occurred about 1.3 and 4.5 times per year in the entire study area. Thus, the number of chemical explosions per year in that area that would have to be discriminated as such from small decoupled nuclear events under a future test ban is small even at the m_b 3.0 level. A major uncertainty pointed out by the OTA Report is, in fact, how many chemical explosions must be contended with per year equal in m_b to that of decoupled explosions of various yields?

Russian scientists stated to me that besides the partially decoupled event of 1976 that four of the other events on the list of Sykes and Lyubomirskiy (1992) were very small nuclear explosions detonated in a water-filled cavity of radius 32m that was created in salt by a previous nuclear explosion. The earliest date of those small explosions, 1975, and the description of a cavity of that radius created by a 25 kt explosion in salt by Kedrovskiy (1970) indicate that the small explosions must have been detonated in the cavity created by the explosion of 1968 at Azgir. Those scientists indicated that two of the events on the list were not nuclear explosions but stated that two yet smaller nuclear explosions that were not on the list had been detonated in the same water-filled cavity on October 30, 1977 and November 30, 1978.

Since nearly all known or inferred Soviet nuclear explosions at Azgir and in the rest of the Pre-Caspian depression were detonated on the hour in a narrow range of local times from 0600 to 1100, I asked Dr. Frode Ringdal to search for possible small signals on those dates in 1977 and 1978 on the Norsar recordings that would have been detonated exactly on the hour during that five-hour time window. He reported that the Hagfors array in Sweden did report P arrivals that were consistent to within a few seconds (Table 2) of events having occurred at Azgir on those two dates at 0700 and 0800 GMT respectively. Norsar, however, was not operational at either of the two expected arrival times. Hagfors recorded all seven of the events in Table 2 that occurred in cavities at Azgir; Norsar recorded five of the events and undoubtedly would have recorded and located the other two if that array had been in operation.

Station corrections for Norsar and Hagfors (and other stations that recorded the explosions in Table 2 of 1975, 1976 and 1979) were used in deriving magnitudes of the seven events. Equation (1) was used to derive approximate yields of the six events fired in the water-filled cavity. It can be seen that the calculated yields of the three smallest events in Table 2 are 0.01 to 0.02 kt. Apparently the small explosions were tested to see if the fundamental frequency of a water-filled cavity surrounded by salt could be excited so as to produce larger than normal seismic waves near that frequency for use in deep seismic sounding. A simple calculation gives a fundamental resonance of about 11.7 Hz; Russian scientists report amplitudes up to five times those of tamped explosions in salt at frequencies of 7 to 9 Hz. Thus, the six events in the water-filled cavity were not tests of decoupling but of enhanced coupling at certain frequencies commonly recorded in deep seismic sounding.

CONCLUSIONS

For purposes of appreciating the detection capability of a given seismic network, it is important to recognize, using data from Azgir, that a fully-coupled (tamped) explosion of 1 kt in salt in high-Q areas of the Commonwealth of Independent States (C.I.S.) has an m_b of 4.4; fully decoupled events of 1 and 10 kt have m_b's of about 2.6 and 3.4 respectively (assuming a decoupling factor of 70). These magnitudes are higher than was generally thought during earlier debates on decoupling. Hence, chemical explosions of $m_b \leq 2.5$ in high Q areas containing salt need not be considered in monitoring a 1 kt threshold treaty or down to that level under a CTBT. Most areas of thick salt deposits in the former U.S.S.R. are typified by high Q (efficient transmission) for P waves and low natural seismic activity. Many of the thick salt deposits of the C.I.S. suitable for construction of large cavities at depth suitable for decoupling, including those few typified by either known natural seismic activity or high attenuation for P waves, are located outside the Russian Republic itself.

Much of the long debate in the United States about the feasibility of conducting and identifying decoupled nuclear explosions in thick salt deposits with yields of say either 1, 10 or 30 kt comes from the very small number--three--of U.S. nuclear explosions in salt, the fact that those events were conducted more than 27 years ago when coverage by sensitive seismic stations and arrays was very limited, and by the very small size, 0.38 kt, of the only U.S. decoupled nuclear explosion in salt, Sterling. Sterling was so small that it was not recorded at teleseismic distances. Environmental considerations, cost and possible continuation of the present testing moratorium will probably prevent the United States in the foreseeable future from conducting a decoupled nuclear explosion in salt in the range 1 to 10 kt (and perhaps from conducting on its territory nuclear events of any size in salt).

The former Soviet Union (FSU), on the other hand, detonated a number of nuclear explosions in salt including tamped events of 1 to 100 kt, a partially decoupled nuclear explosion of 8 kt in the cavity created by a tamped explosion 8 times larger (Adushkin et al., 1993) and six very small nuclear explosions in the water-filled cavity created by the 25 kt explosion of 1968. Clearly, the decoupling experiment of 1976, with a yield 21 times that of Sterling, is crucial to ascertaining decoupling factors for overdriven (partially decoupled) nuclear weapons tests in the yield range from 1 to 10 kt. The release of additional data on that and other events in salt by the Russian Republic would go far in answering longstanding questions in the United States about decoupling, evasion and the ability to detect decoupled events under either a CTBT or a LYTTBT.

Past nuclear explosions conducted in salt by the FSU for which cavities may remain standing that are large enough for the full decoupling of explosions with yields equal to or larger than 0.5 kt are concentrated in only a few areas. The existence of all cavities of that size or larger that were created by past nuclear explosions in the C.I.S. is known (Tables 1 and 3) since the yields of explosions that created those cavities must be at least 20 times larger in yield than the size of a fully decoupled event that can be detonated in them and at least 12 times larger than that of a nearly-fully decoupled explosion (assuming Salmon/Sterling conditions for the latter). Hence, the monitoring of cavities of that type that may remain standing that were created by past nuclear explosions should be relatively easy at the one kiloton level, providing U.S. stations are allowed to operate under the treaty in the vicinity of the epicenters of those past explosions.

Probably the greatest difficulty in monitoring either a LYTTBT or a CTBT involves cavities created, not by past large nuclear explosions in salt, but by solution mining in other areas of thick salt deposits of either the C.I.S. or the U.S. From an analysis of satellite images Sykes et al. (1993) point out, however, that much of the Pre-Caspian region, including all of the area near Azgir, is arid. Hence, Azgir would not be a suitable place for constructing large cavities in salt by solution mining and then using them for clandestine nuclear testing. An understandable question is then why and how, in such an arid environment did the cavities created by the 1966 and 1968 explosions fill with water? Russian scientists have stated that the water that filled the cavity was of underground origin. I do not have information on how long the cavity took to fill except that it must have filled by the time the first explosion was conducted in it in 1975, seven years later.

The 1966 and 1968 explosions were detonated in the Azgir west salt dome whereas the 1971 explosion, for which the cavity remained dry (Adushkin et al., 1993), and other tamped explosions from 1976 to 1979 were conducted in the Azgir east dome about 15 km to the east (Sykes et al., 1993). It is not unusual for considerably higher water pressures to exist at depth in the more permeable sediments surrounding salt domes than in the domes themselves. Fractures created by the 1966 and 1968 events may have permitted water to enter the cavities created by those explosions. Would it be possible to exploit such sub-surface waters for solution mining of large cavities? It should be borne in mind, however, that volumes of water many times those the size of the cavity being created are needed in the solution mining process. Whether such large volumes of water are realistically obtainable at Azgir from nearby sub-surface sources in is not known. Large volumes of water, if they are in fact available, must then be removed from a large cavity in a clandestine manner if it is then to be used for secret decoupled testing. A prime scenario for constructing such a clandestine cavity would be to use an oil or gas field as a cover operation. Drilling associated with the construction of the cavity might be mistaken for that for oil or gas; nearby existing well might be used for disposal of the brine created by solution mining and the emptying of the cavity. Since satellite images reveal that Azgir is not the site of oil or gas exploitation, however, that scenario is not applicable to that and many other areas within the Pre-Caspian depression. Possible clandestine testing in large cavities created by either solution or conventional mining will be dealt with more fully in a separate paper.

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Table 1. Tamped Underground Nuclear Explosions in or Near Thick Salt Deposits of C.I.S.

Area	Date Day Mon. Year	Origin Time Hr. Mn. Sec.	Lat. (°N)	Long. (°E)	m_b	n	Y (mb) in kt*	Y (announced) in kt	Y_{FD} in kt (if ≥ 0.5 kt)
Azgir	22 Apr 1966	02 58 02.1	47.88	47.89	4.524 ± .056	16	1.3	1.1	-
Bukhara II	21 May 1968	03 59 10.0	38.89	65.10	5.4	135		40.	2.0
Azgir	01 July 1968	04 01 59.9	47.91	47.91	5.529 ± .027	20	21.	25.	1.1
Orenburg	25 June 1970	04 59 52.4	52.2	55.7	4.9		3.7		-
Orenburg	22 Oct 1971	05 00 02.1	51.57	54.52	5.260 ± .043	23	10.1	15.	0.7
Azgir	22 Dec 1971	07 00 00.1	47.90	48.13	6.064 ± .020	22	93.	64.	2.7
Kharkov area	09 July 1972	06 59 57.9	49.78	35.45	4.8	62	2.8		-
Lake Aralsor (clay)	20 Aug 1972	03 00 01.2	49.41	48.13	5.750 ± .037	22	39.		2.0
W. of Orenburg	21 Sept. 1972	09 00 01.4	52.19	51.94	5.0	83	4.9		-
NE of Elista (clay)	03 Oct 1972	08 59 57.8	46.86	44.87	5.864 ± .050	21	54.		2.7
W. of Orenburg	24 Nov 1972	09 00 02.9	52.14	51.83	4.5	40	1.2		-
Orenburg	30 Sept 1973	05 00 00.3	51.60	54.51	5.213 ± .047	20	8.9		-
Azgir	29 Jul 1976	05 00 01.4	47.87	48.14	5.884 ± .015	30	57.		2.8
S. of Mirnyy (dolomite)	05 Nov 1976	03 59 56.9	61.52	112.73	5.100 ± .052	16	6.5		-
Azgir	30 Sept 1977	06 59 59.4	47.89	48.15	4.994 ± .029	25	4.8		-
S. of Mirnyy (dolomite)	08 Oct 1978	00 00 00.	61.53	112.87	5.249 ± .034	39	9.8		-
Azgir	17 Oct 1978	05 00 00.0	47.86	48.11	5.851 ± .014	63	52.		2.6

Area	Date Day Mon. Year	Origin Time Hr. Mn. Sec.	Lat. (°N)	Long. (°E)	m_b	n	Y (mb) in kt*	Y (announced) in kt	Y_{FD} in kt (if $\geq$ 0.5 kt)
Azgir (clay)	18 Dec 1978	08 00 00.0	47.85	48.14	5.977 ± .012	65	73.		3.6
Azgir	17 Jan 1979	07 59 59.1	47.92	48.12	6.027 ± .013	58	84.		4.2
Azgir	14 July 1979	04 59 58.8	47.88	48.12	5.620 ± .012	59	27.		1.4
S. of Mirnyy (dolomite)	07 Oct 1979	20 59 56.9	61.85	113.12	5.0	110	4.9		-
Azgir	24 Oct 1979	06 00 00.3	47.85	48.12	5.762 ± .015	69	41.		2.0
Astrakhan	08 Oct 1980	06 00 00.2	46.75	48.24	5.184 ± .038	44	8.2		-
Kuyumba (dolomite)	01 Nov 1980	12 59 58.0	60.79	97.57	5.208 ± .034	40	8.7		-
Astrakhan	26 Sept 1981	05 00 00.2	46.80	48.25	5.146 ± .035	48	7.4		-
Astrakhan	26 Sept 1981	05 04 00.0	46.81	48.26	5.183 ± .034	36	8.2		-
W. Tura	25 Sept 1982	17 59 57.4	64.33	91.80	5.211 ± .034	41	8.8		-
S. of Mirnyy (dolomite)	10 Oct 1982	04 59 56.9	61.53	112.86	5.323 ± .028	40	12.		0.6
Astrakhan	16 Oct 1982	06 00 00.1	46.77	48.20	5.230 ± .033	33	9.3		-
Astrakhan	16 Oct 1982	06 05 00.1	46.75	48.20	5.272 ± .031	36	10.4		0.5
Astrakhan	16 Oct 1982	06 10 00.1	46.78	48.23	5.255 ± .035	35	10.0		0.5
Astrakhan	16 Oct 1982	06 15 00.1	46.75	48.24	5.381 ± .034	42	14.		0.7
Karachaganak	10 July 1983	04 00 00.2	51.35	53.23	5.313 ± .029	48	12.		0.6
Karachaganak	10 July 1983	04 05 00.1	51.35	53.24	5.350 ± .031	48	13.		0.6

Area	Date Day Mon. Year	Origin Time Hr. Mn. Sec.	Lat. (°N)	Long. (°E)	m_b	n	Y (mb) in kt*	Y (announced) in kt	Y_{FD} in kt (if $\geq$ 0.5 kt)
Karachaganak	10 July 1983	04 10 00.1	51.36	53.25	5.235 $\pm$ .027	44	9.4		-
Astrakhan	24 Sept 1983	05 00 00.0	46.79	48.26	5.159 $\pm$ .070	32	7.6		-
Astrakhan	24 Sept 1983	05 05 00.1	46.80	48.23	5.100 $\pm$ .046	31	6.5		-
Astrakhan	24 Sept 1983	05 10 00.0	46.78	48.27	4.996 $\pm$ .046	26	4.9		-
Astrakhan	24 Sept 1983	05 15 00.2	46.78	48.24	5.175 $\pm$ .040	24	8.0		-
Astrakhan	24 Sept 1983	05 20 00.1	46.79	48.22	5.342 $\pm$ .033	31	13.		0.6
Astrakhan	24 Sept 1983	05 25 00.0	46.79	48.24	5.267 $\pm$ .044	29	10.3		0.5
Karachaganak	21 July 1984	03 00 00.0	51.34	53.24	5.331 $\pm$ .028	52	12.3		0.6
Karachaganak	21 July 1984	03 04 59.9	51.38	53.26	5.264 $\pm$ .026	52	10.2		0.5
Karachaganak	21 July 1984	03 10 00.0	51.35	53.25	5.323 $\pm$ .026	49	12.		0.6
Astrakhan	27 Oct 1984	06 00 00.2	46.88	48.11	5.018 $\pm$ .042	38	5.2		-
Astrakhan	27 Oct 1984	06 05 00.1	46.86	48.03	5.082 $\pm$ .046	38	6.2		-
Perm Region (limestone)	19 Apr 1987	03 59 57.1	60.62	57.2	4.5	17	1.2		-
Perm Region (limestone)	19 Apr 1987	04 04 55.9	60.8	57.5	4.5	19	1.2		-
S. of Mirnyy (dolomite)	06 July 1987	23 59 56.9	61.50	112.83	5.1	70	6.5		-
S. of Mirnyy (dolomite)	24 July 1987	01 59 56.9	61.46	112.78	5.1	65	6.5		-
S. of Mirnyy	12 Aug 1987	01 29 57.1	61.46	112.79	5.0	60	4.9		-

Area	Date Day Mon. Year	Origin Time Hr. Mn. Sec.	Lat. (°N)	Long. (°E)	m_b	n	Y (mb) in kt*	Y (announced) in kt	Y_{FD} in kt (if ≥ 0.5 kt)
SE side, Pre-Caspian depression	03 Oct 1987	15 14 57.7	47.62	56.20	5.3	65	11.		0.6
E. of Kotlas (anhydrite, dolomite)	06 Sept 1988	16 19 58.7	61.33	47.98	4.8	57	2.8		-

* calculated from $m_b = 4.4250 + 0.832 \log Y$

Table 2. Nuclear Explosions in Cavities in Salt at Azgir

Date	Hr.	Min.	$m_b \pm$ SEM	$n(m_b)$	Yield (kt)
25 Apr. 1975	05	00	4.45 ±.13	7	1.1
*29 Mar. 1976	07	00	4.06 ±.04	7	8**
14 Oct. 1977	07	00	3.42	1	0.06
30 Oct. 1977	07	00	2.77	1	0.01
12 Sept 1978	05	00	3.02	1	0.02
30 Nov. 1978	08	00	3.07	1	0.02
10 Jan. 1979	08	00	4.36 ±.14	2	0.8

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*In air-filled cavity created by 64 kt explosion of 1971; all other events in water-filled cavity created by 25 kt explosion of 1968.

**Yield of 1976 event from Adushkin et al.(1993); other yields, Y, from $m_b = 4.425 + 0.832 \log Y$

Table 3. Inventory of Large Cavities Produced by Past Nuclear Explosions in or near Thick Salt Deposits of C.I.S. that may Remain Standing that might be used to Conduct Fully Decoupled Nuclear Tests of Yield, $Y_{FD} \geq 0.5$ kt.

REGION	Y_{FD}(kt)				
	0.5-0.9	1.0-1.9	2.0-2.9	3.0-3.9	4.0-4.2
Pre-Caspian Depression					
Azgir		2	4	1*	1
Astrakhan	5				
Karachaganak	5				
Lake Aralsor			1*		
Other	2		1*		
Bedded salt to NW of Lake Baikal	1				
Central Asia - Bukhara			1		
Totals	13	2	7	1*	1

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* Reported by Russian workers as detonated in clay

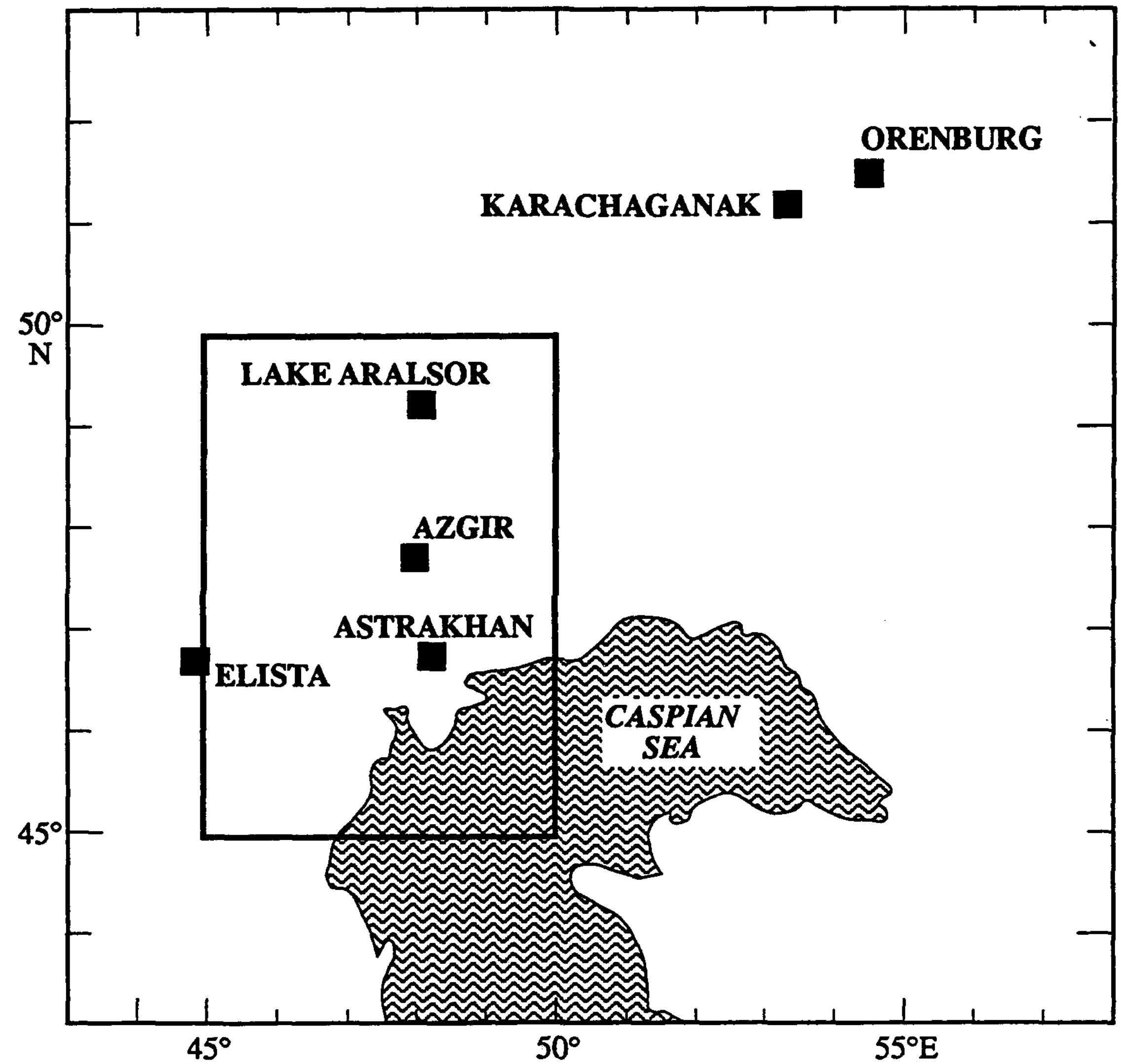

Fig. 1. North Caspian Region showing sites of nuclear explosions in and near thick salt deposts (squares) in Pre-Caspian depression and area of special study of small seismic events (boxed region).

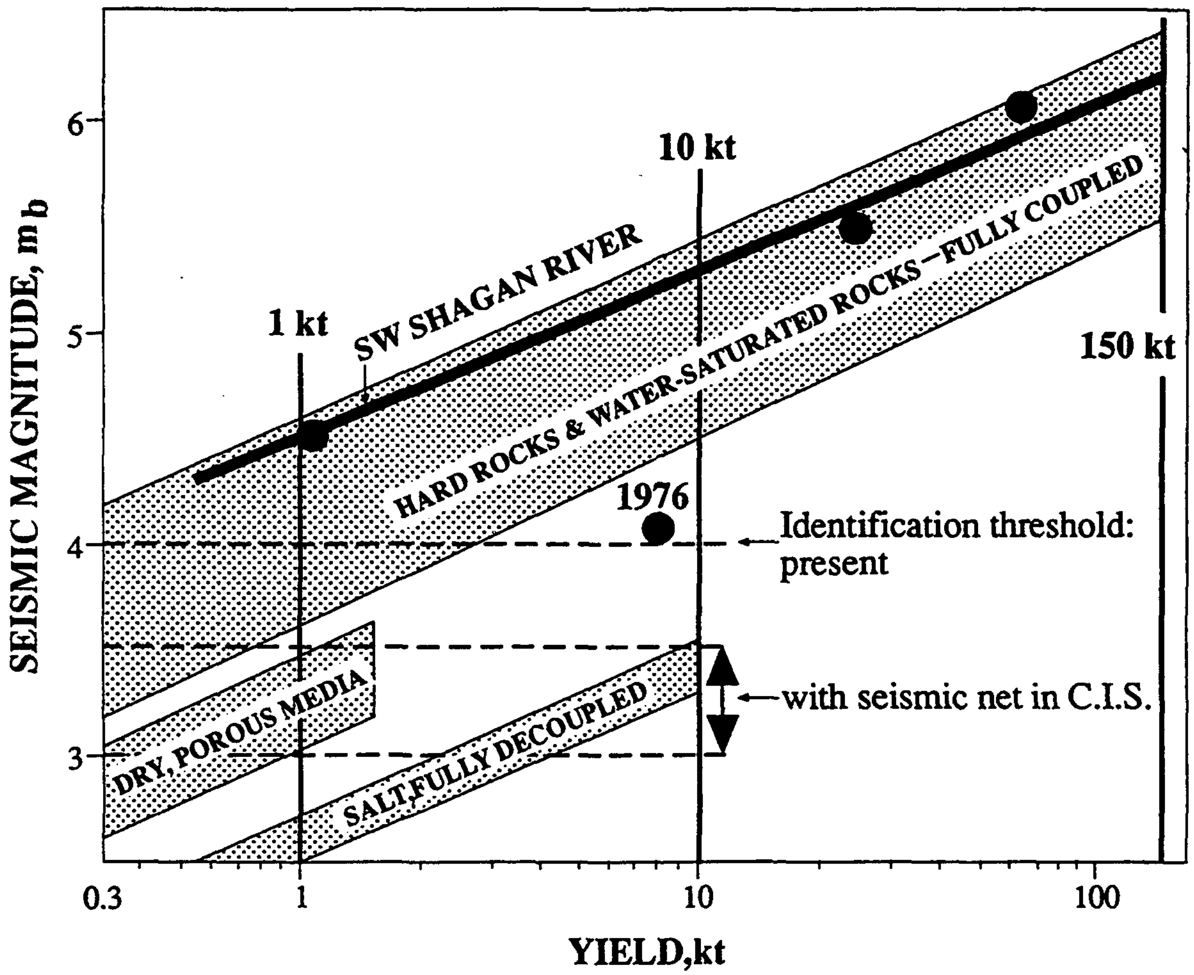

Fig. 2. Seismic magnitude as a function of yield for underground nuclear explosions conducted under various testing conditions (hatched areas) in Commonwealth of Independent States (C.I.S.). SW Shagan River denotes regression line for fully-coupled nuclear explosions in southwestern part of that testing area in eastern Kazakhstan (Sykes, 1992). Three upper dots denote data points for fully-coupled explosions in salt at Azgir; dot labelled 1976 denotes partially decoupled explosion at Azgir of March 1976; 150 kt denotes yield limitation of Threshold Test Ban Treaty. Present identification threshold using seismic stations solely external to C.I.S. and range of thresholds with seismic network in C.I.S. from Office of Technology Assessment (1988).

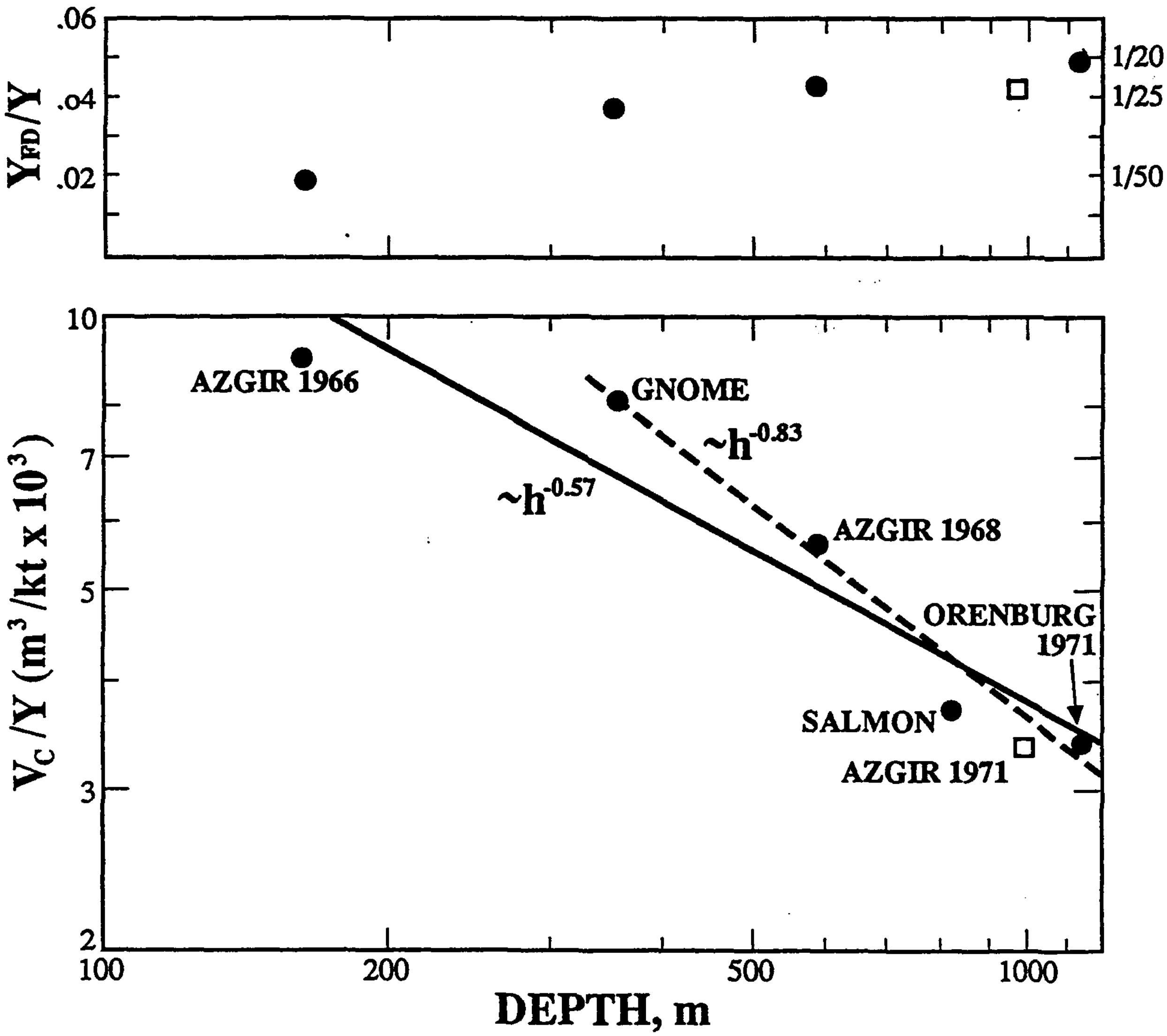

Fig. 3. Top: Calculated maximum fully-decoupled yield, Y_{FD}, divided by yield, Y, of tamped explosion creating a cavity of usable volume V_C as a function of depth, h, for tamped nuclear explosions in salt for which information has been released on Y, h and V_C. Data from 1971 explosion were not included in either two regression lines shown. Solid line is regression based on data from four other explosions; dashed, that based on those four data points minus that for shallow event of 1966.

ACCURATE RELOCATION OF NUCLEAR EXPLOSIONS AT AZGIR, KAZAKHSTAN, FROM SATELLITE IMAGES AND SEISMIC DATA : IMPLICATIONS FOR MONITORING DECOUPLED EXPLOSIONS

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Abstract. The 10 largest tamped nuclear explosions detonated by the Former Soviet Union in and near two salt domes near Azgir were relocated using seismic data and the locations of shot points on a SPOT satellite image taken in 1988. Many of the shot points are clearly recognized on the satellite image and can be located with an accuracy of 60 m even though testing was carried out at those points many years earlier, i. e. between 1966 and 1979. Onsite inspections and a local seismic monitoring network combined with our accurate locations of previous explosions would insure that any cavities that remain standing from those events could not be used for undetected decoupled nuclear testing down to a very small yield. Since the Azgir area, like much of the Pre-Caspian depression, is arid, it would not be a suitable place for constructing large cavities in salt by solution mining and then using them for clandestine nuclear testing.

Introduction

The former Soviet Union (FSU) conducted a large number of nuclear explosions in thick salt deposits, especially in the Pre-Caspian depression to the north of the Caspian Sea, the world's largest salt dome province. Most of the larger explosions were conducted near the small town of Azgir in westernmost Kazakhstan, a remote site which appears to have been a Soviet testing area for nuclear explosions for peaceful purposes [Sykes, 1991]. A major issue in the monitoring of treaties to further limit or ban nuclear testing has been the possibility that large cavities in salt domes created by either past large nuclear explosions or solution mining could be used to reduce the amplitudes of seismic waves of small nuclear explosions detonated in those cavities [Office of Technology Assessment, 1988]. An event of that type is a so-called decoupled explosion. The FSU detonated several nuclear explosions in large cavities created by tamped (full coupled) events at Azgir, including a partially decoupled explosion of eight kilotons (kt) in 1976 in an air-filled cavity created by a 64 kt explosion in 1971 [Sykes and Lyubomirskiy,1992; Adushkin et al., 1993].

To better identify attempts to use cavities of that kind for future decoupled nuclear testing, it is helpful to know accurately the locations of past large nuclear explosions in salt domes and other thick salt deposits. In this paper we use images from the SPOT satellite and seismic data to relocate the 10 largest tamped nuclear explosions at Azgir. From the SPOT data taken in 1988 we obtain absolute locations of likely shot points of these events, which occurred from 1966 to1979. We use P-wave arrival time data from large numbers of seismic stations for each explosion to obtain relative locations with respect to a master event so as to identify the shot locations on SPOT images that correspond to explosions detected seismically on specific dates. Thurber et al. [1993] used a similar technique to associate shot positions at the Balapan (Shagan River) portion of the eastern Kazakhstan nuclear weapons test site with dates of explosions detected seismically. Leith and Simpson [1990] discuss the use of satellite images in locating seismic events. Marshall et al. [1991] used the Joint Hypocentral Determination (JHD) method to obtain relative locations of 9 of the 10 Azgir events we studied. We include newly released arrival times for the 10 events from standard seismograph stations in the FSU. In addition we comment on monitoring the Azgir region under possible future treaties to ban or limit the testing of nuclear weapons and on the unsuitability of the arid Azgir region for the construction of large cavities by solution mining.

Data and Methods

We purchased the digital data for three spectral bands of the SPOT imagery taken on September 14, 1988. It covers a region 60 by 60 km centered on 47°59.9'N, 48°01.5'E with a pixel size of 20 m. In our work we processed a number of images of that area and portions thereof. Fig. 1 is a 30 by 20 km part of the original image. The town of Azgir is located at the convergence of roads at the lower left. Clear indicators of past nuclear testing, including disturbed areas and convergence of roads near shot points, can be seen in the area 14 to 18 km to the east and northeast of Azgir. Seven of the eight shot points in that area are clearly visible on the satellite images. Two other areas of ground disturbance and convergence of roads about 6 to 8 km NNW of Azgir, as we will see from the relative seismic locations, appear to have been the shot points of the 1.1 kt explosion of 1966 and the 25 kt event of 1968 [Kedrovskiy, 1970; Sykes, 1991]. The southernmost shot point of the two, which we associate with the 1966 explosion, is less clear on Fig. 1. We used locations of about 30 road intersections from available maps to provide absolute locations for points on the SPOT image. Individual shot points can be measured with an accuracy of about 60 m (one standard deviation).

In obtaining our seismic locations we used the P wave arrival times from seismic stations within 100^{o} of Azgir from the bulletins of the International Seismological Center (ISC) and standard stations of the national network of the FSU. Fig. 2A shows the 359 stations in that distance range that reported one of the largest Azgir events, that of October 17, 1978, and Fig. 2B shows the stations that reported both that event and the small event of 1.1 kt in1966. The master-event technique [Bullen and Bolt, 1985] was used to calculate the relative locations and origin time corrections of the nine other events in Table 1 with respect to the master event of October 17, 1978. The depths were held fixed in the calculations. The IASPEI91 earth model was used to calculate ray-parameters. We assumed that the data for a given event with respect to the master event satisfy a normal distribution, and used a Gaussian weighting function to improve the results and minimize uncertainties. We calculated 95% confidence ellipses for the relative epicentral location of each event and show them in Figs. 3 and 4 and Table 1. From Table 1 it is clear that at least 124 stations were used in the relocations except for the smallest event, that of 1966, for which 42 relative P times were available.

Results

Table 1 lists the events studied, their revised locations and origin times. The origin time of the master event of October 17, 1978 was set at 05 00 00.0 UCT. The origin times of the other 9 explosions were calculated using the calculated hours and minutes in the ISC bulletins and then adding to zero seconds the time corrections calculated with respect to the assumed origin time of the master event. The uncertainty in the calculated time corrections is smaller than 0.1 s. The fact that two of the 9 events have calculated origin times within 0.1 s of an exact hour argues strongly that those events and the master event, in fact, occurred exactly on an hour to within 0.1 s. Likewise, the 1968 event occurred within 0.1 s of an exact minute. All of the events from 1971 to

1979 occurred within 1.4 s of an exact hour. It is a common procedure for nuclear explosions of many countries to be scheduled and then detonated either on an exact hour or minute since the activities of many people and much equipment at many locations involved in monitoring nuclear tests must be coordinated.

The relative locations also show two distinctive groupings of explosions (Fig. 3). The first group consists of the two early explosions of 1966 and 1968, which were detonated north of the town of Azgir in the west Azgir salt dome [Kedrovskiy, 1970; Ministry of Geology, 1983]. The other explosions from 1971 to 1979 were detonated about 18 km east of the first group (upper-right Fig. 1) in the east Azgir salt dome [Ministry of Geology, 1983; Adushkin et al. 1993]. Fig. 4, which is an expanded view of the northeastern part of Fig. 3, indicates our preferred match between SPOT image measurements and seismic locations. Only one of the shot points on the SPOT image in Fig. 4 is somewhat uncertain; the others are very clear picks. The locations from the satellite image in Fig. 4 are more tightly clustered, especially in the east-west direction, than the seismic locations. Since the salt structures in the Azgir area have an upper relief of several kilometers, the use of a standard, spherically symmetrical velocity model in computing the relative seismic locations probably contributes to the blurring of the seismic image.

When the seismic location of the master event is co-located with the shot point we associate with it on the SPOT image, the seismic locations of the other events exhibit a systematic bias in latitude with respect to the SPOT locations. To reduce that bias we allowed the seismic and satellite locations of the master event to differ. We obtained the match in Fig. 4 by minimizing the sum of the squares of the lengths of the arrows connecting the inferred locations by the two methods. That procedure also resulted in the centroid of the seismic locations exactly coinciding with that from the satellite locations. In that case six of the seven 95% confidence ellipses in Fig. 4 overlap at least one possible shot point measured from the SPOT image. The confidence ellipses are generally elongated in the northeast-southwest directions, indicative of the smaller number of stations in those quadrants (Fig. 2).

Russian scientists have stated in writing to us that the explosion on Dec. 18, 1978 was detonated in clay while all of the other events at Azgir were detonated in salt. That event is correlated in Fig. 4 with the only shot point in Fig. 1 for which the false color of the disturbed area near it is red and not white. It is also the only event for which the 95% confidence ellipse does not overlap the corresponding shot point in Fig. 1. An alternate solution is to associate the master event with the southernmost shot point on the satellite image. In that case, however, a large misfit in seismic and

SPOT locations cannot be avoided for the explosion of Dec. 18, 1978. In all of these solutions, however, the association of shot points with seismic locations remains the same for the four northernmost events of Fig. 4.

Our relative seismic locations are very similar to those obtained by Marshall et al. [1991]. Their epicenters differ from the satellite locations on the average by only 2.9 km. The ISC locations show more scatter and differ from the satellite locations on the average by 8.4 km.

Shot depths of 165, 590 and 987 m are published for the explosions of 1966, 1968 and 1971 [Kedrovskiy, 1970; Adushkin et al., 1993]. Since the calculated origin time of the 1971 event in Table 1 is within 0.1 s of an exact hour, we can consider the depths of all of the events, including the master, to be normalized to that of the 1971 event, 987 m. Correcting the 1966 and 1968 events for difference in depth of focus with respect to the 1971 explosion using a salt velocity of 4.2 km/s [Adushkin et al., 1993] would make their origin times earlier than those in Table 1 by 0.2 and 0.1 s. Hence, differences in origin time larger than a few tenths of a second are unlikely to be associated with different depths of detonation. Thus, most of the departures of the calculated origin times from an exact minute in Table 1 probably reflect that some of them were detonated as much as 1 or 2 s off an exact minute or that large differences in structure exist at depth beneath the various shot points.

Some of the shot points to the northeast of Azgir in Fig. 1 are characterized by at least two nearby disturbed areas. Some of these may be additional holes drilled for instrument implacement. What we identify as the location of the 1971 explosion in Fig. 4 is characterized by two disturbed areas about 200 m apart of nearly equal intensity in Fig. 1. One of these could be the re-entry hole into the 1971 cavity that was used for the implacement of the device for the partially decoupled explosion of 1976 [Adushkin et al., 1993].

Discussion

Eight of the ten shot points of nuclear explosions conducted near Azgir from 1966 to 1979 are clearly visible on the satellite images taken in 1988. The seismic and satellite data taken together result in quite accurate locations for all 10 events. A combination of onsite inspections, repeated satellite imagery of high resolution and a local seismic monitoring network would insure that any cavities that remain standing from those events could not be used for undetected decoupled nuclear explosions down to a very small yield. The NORSAR and Hagfors arrays can detect small events of body wave magnitude as low as 2.5 from the Azgir region [Ringdal, 1981; Ringdal and Husebye, 1982; Sykes and Lyubomirskiy, 1992]. Since they are located more than 2000 km from Azgir, the location capability of those arrays by themselves is poor compared with that of a local seismic network. Sykes and Lyubomirskiy [1992] found that the rate of occurrence of chemical explosions in a large area surrounding Azgir is low and that of small earthquakes is even lower. Several small events at Azgir that occurred almost exactly on the hour from 1975 to 1979 are taken to be small nuclear explosions and will be the subject of another paper.

An examination of Fig. 1 and of the entire 60 by 60 km SPOT image that we processed indicates that the region is arid and sparsely populated. The many salt flats and small playa lakes in Fig. 1 and in the larger image indicate a lack of fresh water in almost all of the area. Several small rivers of the Pre-Caspian depression drain into ephemeral lakes [Ministry of Geology, 1983] and not into the two major rivers of the region, the Ural and Volga, that drain into the Caspian Sea. On most of the 60 by 60 km SPOT image the percentage of cultivated land is even smaller than that in Fig. 1. The area near Azgir, like much of the Pre-Caspian depression, would not be one in which large cavities in salt domes could be constructed by solution mining since that process requires great quantities of fresh water. Therefore, it would be practical to excavate such cavities for clandestine decoupled nuclear testing in the Pre-Caspian depression only in a few areas near major rivers and along the coast of the Caspian Sea.

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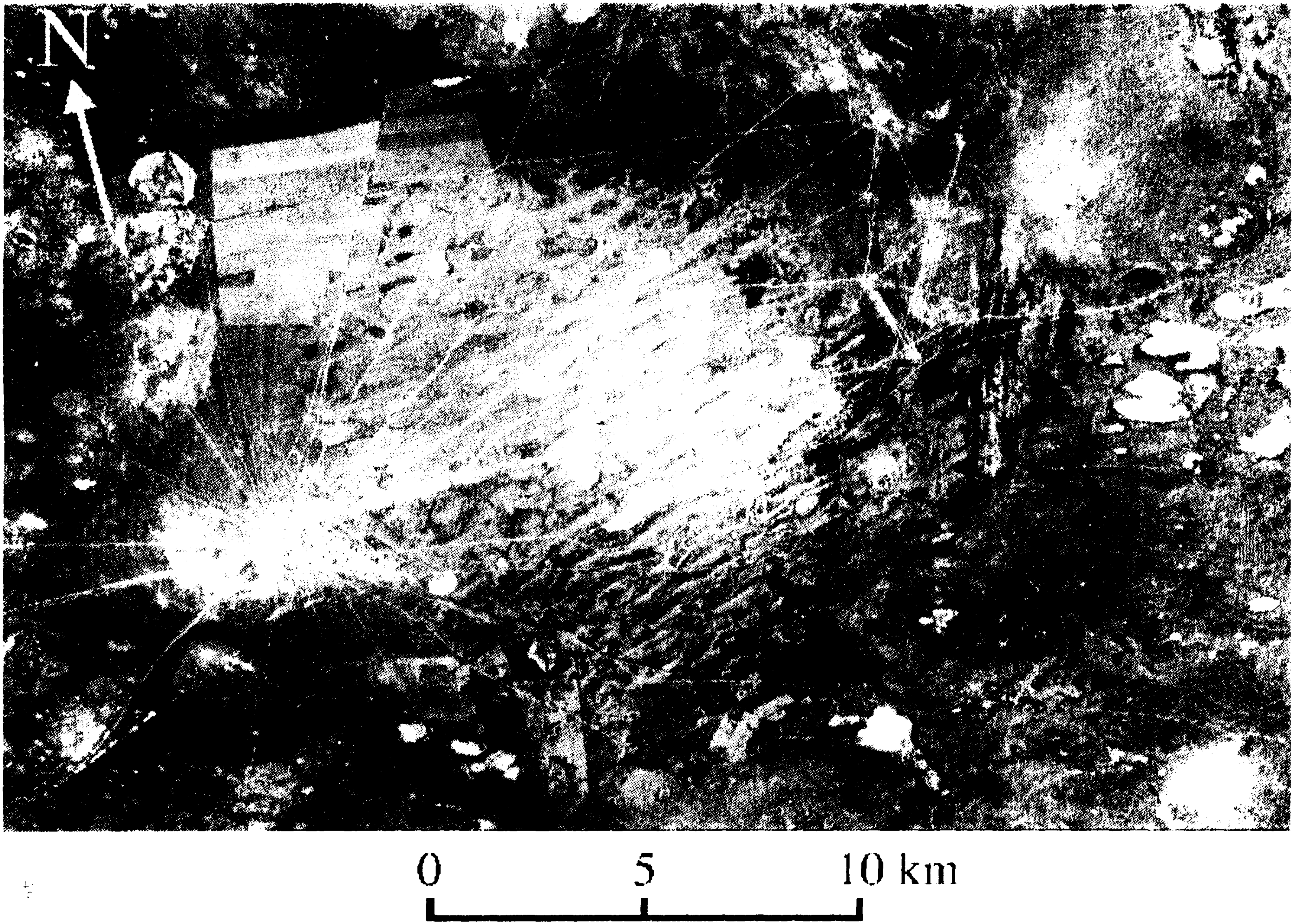
TABLE 1. Origin Times and Locations for the 10 Largest Nuclear Explosions Near Azgir.

Date			Origin Time			SPOT Location		95% Confidence Ellipses[1]			Number of
Day	Mon.	Year	Hr.	Mn.	Sec.	Lat.(N)	Lon.(E)	Maj.(km)	Min.(km)	Angle	Stations
22	Apr.	1966	02	58	02.1	47°53.02'	47°53.32'	6.6	6.3	-28.5	42
01	July	1968	04	01	59.9	47°54.54'	47°54.84'	4.2	3.0	64.4	124
22	Dec.	1971	07	00	00.1	47°53.80' 47°53.79'	48°07.82' 48°07.66'	2.5	1.8	35.9	170
29	July	1976	05	00	01.4	47°52.25'	48°08.32'	2.4	1.6	45.1	216
30	Sept	1977	06	59	59.4	47°53.27'	48°09.13'	3.2	2.3	47.9	129
17	Oct.	1978	05	00	00.0	47°51.82'	48°06.81'				359
18	Dec.	1978	08	00	00.0	47°51.11'	48°08.65'	2.0	1.3	41.8	281
17	Jan.	1979	07	59	59.1	47°55.14'	48°07.30'	2.2	1.3	45.3	252
14	July	1979	04	59	58.8	47°52.89'	48°07.20'	2.1	1.4	40.2	248
24	Oct.	1979	06	00	00.3	47°50.78'	48°07.36'	2.2	1.4	35.2	266

1. Maj. and Min. are dimensions of semi-major and semi-minor axes of confidence ellipse. Angle in degrees from north to one of semi-major axis; clockwise is positive.

Fig. 1. Digitally processed image of SPOT photography taken on September 14, 1988 of nuclear testing areas near Azgir, west Kazakhstan. The latitudes and longitudes of the four corners clockwise from the northwestern are as follows: 47°58.19'N, 47°52.23'E; 47°54.36'N, 48°15.95'E; 47°43.77'N, 48°12.11'E; 47°47.60'N, 47°48.43'E. Town of Azgir is located at convergence of roads at lower left. Sites of eight explosions from 1971 to 1979 can be seen at upper right of center where shot points and roads are still clearly visible. Two explosions in 1966 and 1968 occurred to the north of Azgir in a separate area. (Image made from base photo, © 1988, CNES/SPOT Image Corporation.)


N
0
5
10 km

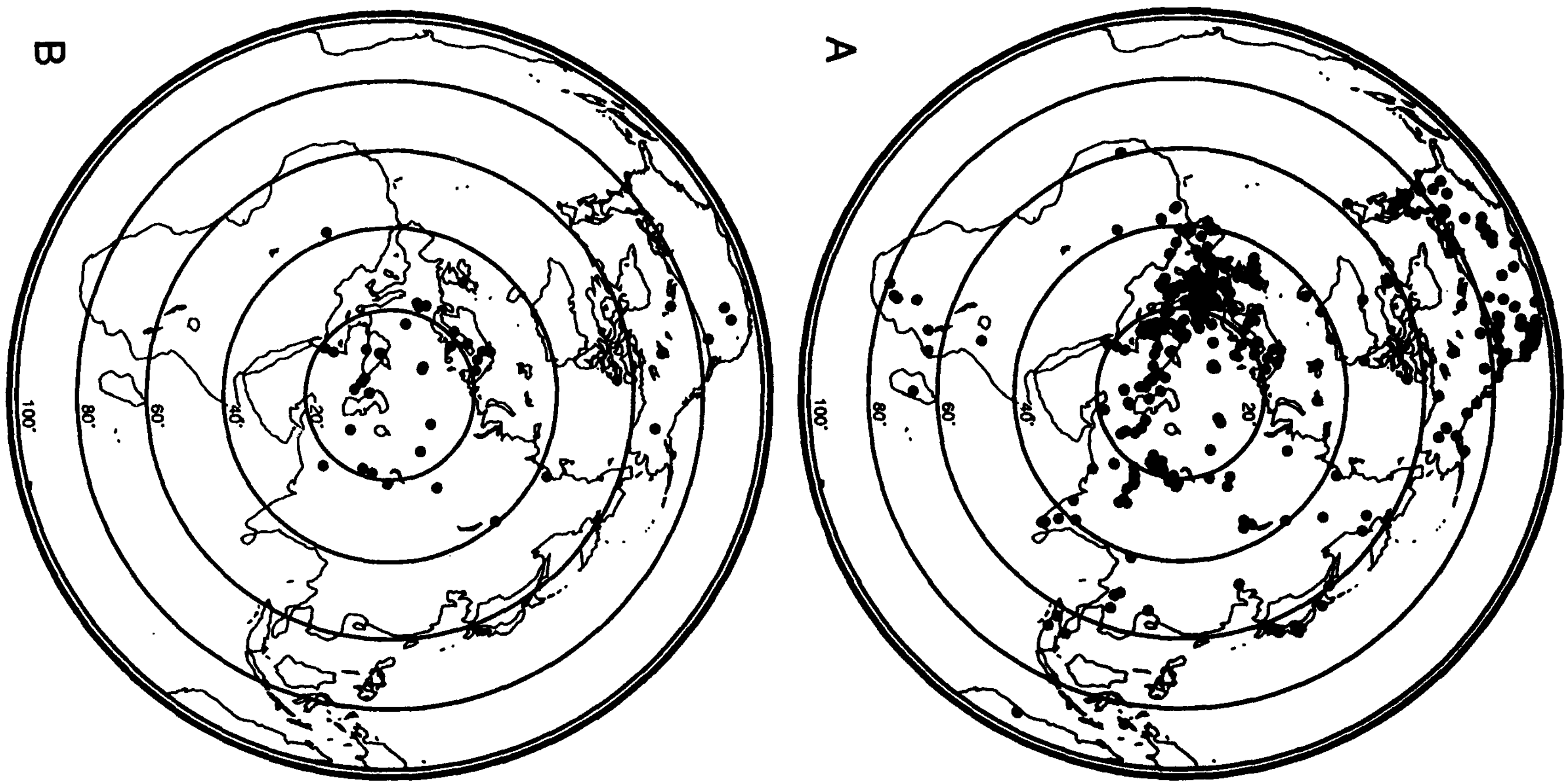


Fig. 2. (A). Station distribution centered on master event of Oct. 17, 1978. Stations farther than 100^{o} were not used in this study. (B). Stations that reported both the master event and the small event of 1.1 kt on April 22, 1966.

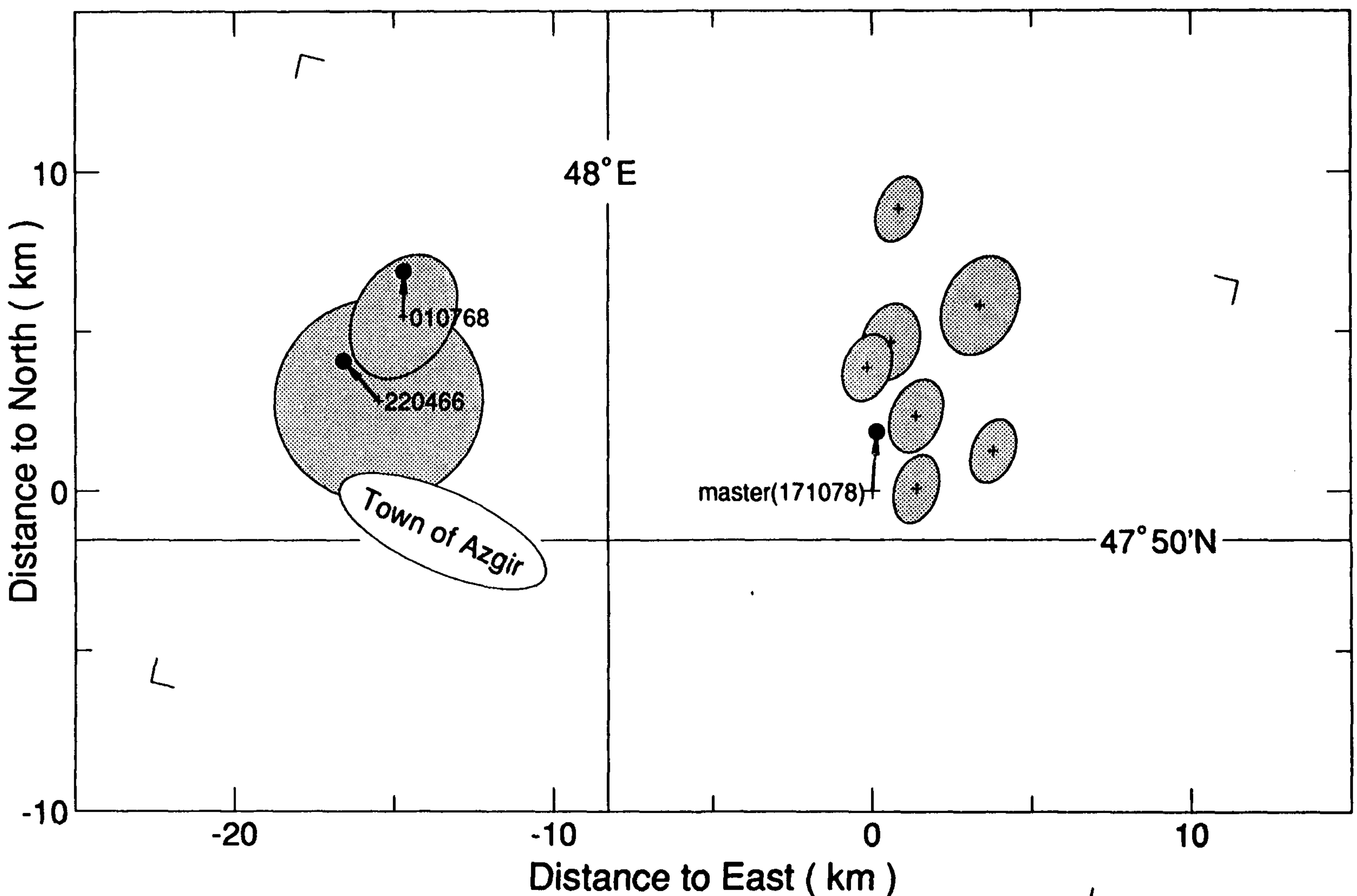


Fig. 3. Calculated relative locations (pluses) of Azgir explosions with respect to master event with 95% confidence ellipses. Three solid circles are possible sites of nuclear explosions from the SPOT image of Fig. 1. On right hand side, only the inferred SPOT location of the master event is plotted. Town of Azgir is at lower left corner.

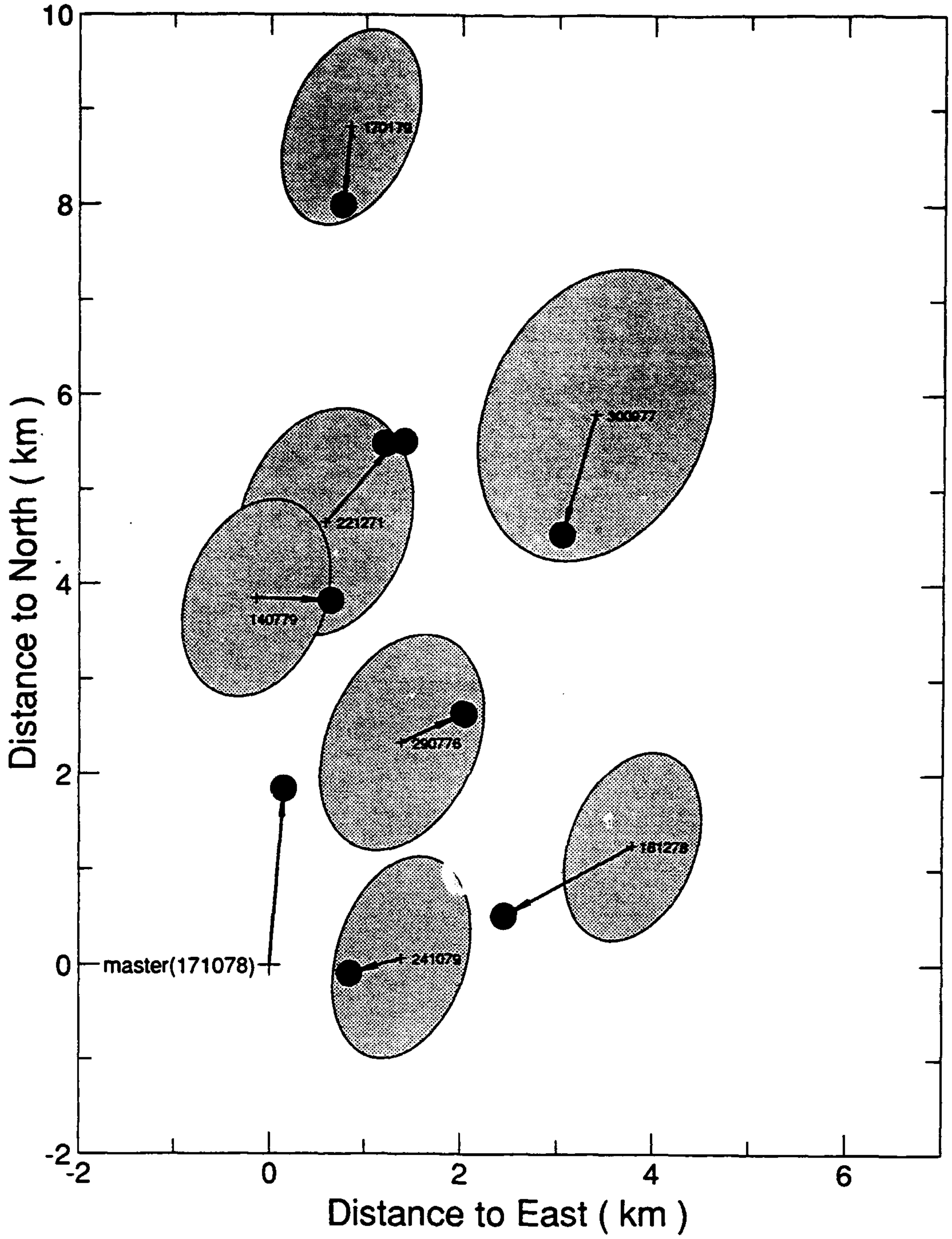


Fig. 4. Enlarged view of testing area in Fig. 3 to northeast of town of Azgir. Arrows connect relative loc: ions from seismic data (pluses) with inferred shot points from SPOT image (solid circles). Confidence ellipses indicate uncertainties in seismic locations for other explosions with respect to master event. Event of Dec. 18, 1978 was detonated in clay; all others were in salt.

CATALOG OF REPORTS FROM STANDARD STATIONS OF USSR FOR TEN TAMPED NUCLEAR EXPLOSIONS AT AZGIR

(Provided by D. D. Sultanov)

22.04.1966г. (Севернее Каспийского моря – АЗГИР-I)

(02-58)

ISC: H=02-58-04,0
φ =47,93°N
λ =47,69°E h=0км
MB = 4.7

ЕССН: 0-02-58-02,27
φ = 47,796°N
λ =47,917°E h =0км
расчет – h =33км

Севернее Каспийского моря

№ пп	Станция	Az°	Δ°	Приб.	Фаза	Время	T сек	A мк NS	A мк EW	A мк Z	Mag	R
1.	Грозный (GRO)		4,55ˣ	СК	eeP	02-59-15	1,0			0,4		
					S	03-00-48	1,8	0,62				
					L_R	02-04	9,0			0,6	3,20Mk	
2.	Махачкала (MAK)		4,7ˣ	СК	ePсю	02-59-17,8	0,6	0,53				
					L_R	03-06-02	7,0			0,32	3,09Mk	
3.	Кр.поляна (KPR)		6,4ˣ	СКМ	iP_1	02-59-41,8	0,5			0,038		
					P_2	03-00-16,8	0,6			0,053		
4.	Бакуриани (BKR)		6,5ˣ	СКМ	iP	02-59-42,8	0,9			0,485		
				СК			1,0			0,1		
				СКМ	iX	03-00-31,0	1,0			0,003		
5.	Абастумани (ABS)		6,6ˣ	ВСХ	eP	02-59-45						
6.	Гори (GOR)		6,7ˣ	СКМ-3	eeP	02-59-45,5	0,8			0,071		
					$S_{iвз}$		1,1		0,128			
					$S_{2сю}$	03-01-57,5	2,6	0,159				
7.	Кировабад		6,8ˣ	СК	P	02-59-47,0						
	Сочи		6,8ˣ	СКМ	iP_1	02-59-47,0	0,5			0,12		
					P_2	49,0	0,6			0,08		
9.	Степанован		6,9ˣ	СХ	eP	02-59-48,4						
10.	Горис	188	8,3	СК	eP	03-00-04						–0,
11.	Алушта		9,3ˣ	СХ	eP	03-00-22,3						
12.	Ялта		9,5ˣ	СХ	iP_I	03-00-25,1	0,45			0,033		
					iP_2	37	0,6			0,023		
13.	Обнинск		9,5ˣ	Бен-Z	eP	03-00-24,6						
14.	Ст. №1 (Михнево)		9,5ˣ	СКМ	iP	03-00-26	0,45			0,123		
				УСФ	iP		0,4			0,142		
				СКМ	S	02-00,5	0,65			0,072		
				УСФ			0,8			0,129		
				СК			0,8			0,167		

22.04.66

№ пп	Станция	Az°	Δ°	Приб.	Фаза	Время t	T сек	Aμ NS	Aμ EW	Aμ Z	Mag	Res
15.	Свердловск		11,1ˣ	СКМ-3	eP	03-00-47,0						
16.	Симферополь		11,25ˣ	СХ	eeP	03-00-49,0	1,0		0,057			
17.	Ашхабад		11,9ˣ	СК	eP	03-01-03						
18.	Боровое		14,6ˣ	СКМ	eP	03-01-32,9	0,8			0,006		
					(S)		1,0		0,008			
19.	Рахов		15,1ˣ	СКМ	eP	03-01-39,5						
20.	Межгорье		15,55ˣ	СКМ	eX_z	02-05,2						
21.	Куляб		16,0ˣ	СКМ	eP	03-01-51,8						
22.	Ужгород		16,4ˣ	СКМ	eP	03-01-57,3	0,6			0,016		
23.	Гарм	110	18,4	СКМ	eP	03-02-16,8				0,03		
24.	Андижан		18,6ˣ	СКМ	P	03-02-23,4	0,6			0,07	5,07 MPV	
25.	Джергиталь		18,85ˣ	ВЭГИК	P	03-02-27,1	0,1					
26.	Или		20,1ˣ	СК	eP	03-02-41,4						
27.	Апатиты		20,3ˣ	СКМ	M LR	03-02-44 26,2	18	1,4	1,1			
28.	Талгар	91	20,9	СК	iP_z	03-02-45,4						-5,5
29.	Курменты		21,3ˣ	СКМ	eP	03-02-53,2						
30.	Усть-Каменогорск		21,9ˣ	УСФ-3М	iP	03-02-59,6	0,8			0,017	4,52 MPV	
31.	Ельцовка		24,2	СКМ	eP	03-03-22,5	0,8			0,02	4,75 MPV	
32.	Чаган-Узун		25,9ˣ	СКМ	eP	03-03-39,2	1,2			0,02	4,67 MPV	
33.	Бодайбо	49	39,7	СКМ	iP	03-05-34	0,6			0,026		+0,8
34.	Тикси	27	42,7	СКМ-3	iP	03-05-58	0,9			-0,005	4,45 MPV	-0,3
35.	Иультин	18	59,4	СКМ-3	eP	03-08-03,5	0,8			-0,012	5,08 MPV	+0,7
36.	Мирный	161	119,0	СКМ	ePKP	03-15-00						
					e	18-15						

(01 July 1968)
I.УП.1968г. (Севернее Каспийского моря - АЗГИР-2) - Зап. Казахстан
(04-02)

ISC: H=04-02-00,9
φ=47°,85 N
λ=47°,72E h=0км
MB = 5,5

ЕССН:0=04-0I-57,6
φ=48°,005N
λ=47°,850E h=0км
MPV

Севернее Каспийского моря

№№ пп	Станция	Az°	Δ°	Приб.	Фаза	Время	Aм NS	Aм EW	Aм Z	T сек	Mag	Res
I	2	3	4	5	6	7	8	9	I0	II	I2	I3
I.	Грозный		4,5ˣ	СК-Z	P	04-03-I3,0						
				E	i	4I,5						
				E	(S_2)	04-50,5						
					S max		5,6	5,2	2,0	I,0		
					ML		4,2	2,4	3,4	8,0	4,7 ML	
2.	Махачкала	36	4,7	СК-Z	iP	04-03-I5,6				6		
					eLg	05-40						
					eLR	07-I8,6	4,3	4,0	4,0	8,0	4,I3 ML	
3.	Пятигорск	22I	5,2	СК	eP	04-03-I7,0						+0,9
					e	24						
					ePg	38						
4.	Тбилиси	200	6,7	СК	P_2	04-03-37,0						-0,3
					eNE	04-I2						
					eS_2NE	05-50						
					eLg,NE	07-00						
5.	Гори		6,7ˣ	СВКМ-3	i	04-04-08						
6.	Абастумани		6,7ˣ	ВСХ	+iP	04-03-44						
				$ГСХ_E$	i	04-I8						
7.	Степанован		6,85ˣ	СХ	iP	04-03-45,2						
					i	04-42,2						
					iS_1	05-03,2						
8.	Анапа		7,4ˣ	СКМ	iP	04-03-53,5						
					e	56						
9.	Бакуриани	207	7,0	СКД-Z	eP	04-03-4I,5						
				"	i	55,5						
				СК-Z	e	57,5						
				"	i	04-I4,5						
				"	i	I8,I						
				" B	i	2I,5						

1	2	3	4	5	6	7	8	9	10	11	12	13
9.	Бакуриани (прод)				i	04-04-29,0		0,9		1,0		
					i	38,6	1,0			1,0		
					iS1	51		1,7		1,2		
					i	06-24,1						
					L	08,2	0,6			9,0	3,49	
10.	Ереван		7,6^x	СК	eP2	04-03-56,6						
11.	Горис	187	8,6	СК	-iP	04-04-02			-0,2	1,0		+1,
					eP2	14						
					e	06-59						
					eS1	07-04						
					eS(Lg)	08-01						
12.	Феодосия		8,6^x	СК	eP	04-04-11						
					eS1	05-53						
					eX	06-03						
					eX	19						
13.	Алушта		9,3^x	СХ	-iP	04-04-20,1						
					Pmax	21			0,5	0,7		
					eX	36,4						
					eS1	05-52,7						
14.	Ялта		9,6^x	СХ-Z	eP	04-04-23,5						
					Pmax	24,0	0,2	0,3	-0,5	0,5		
15.	Симферополь	257	10,0	СК-Z	eP	04-04-20						+2,
				" В	eX	31						
					iX	55						
				" С	e(S)	05-37						
16.	Москва	324	10,0	СВХ	eP	04-04-22						+0.
				"	i	24						
				СВКN	e	34						
				"		46						
				"	e	05-12						
				СГК	e	06-12						
					e	07-06						
					e	10						
					eS2	31						
				СК	ML		0,4		0,6	8,0	3,88 ML	
				СКД	MLg2	09,5	0,4		0,5	8,0		
				СВКД	ML				0,3	9,0		

I	2	3	4	5	6	7	8	9	I0	II	I2	I3
I7.	Кизыл-Арват	I42	I0,7	СК	eP_2	04-04-33						-0,[illegible]
					eN	05-0I						
I8.	Свердловск	36	II,8	СВКМ-3	P	04-04-44						+3,2
					M	II	0,5	0,5	0,9	II,0	3,94мк	
I9.	Ванновская	I39	I2,5	ВЭГИК	eP	04-04-59						+I,4
20.	Ашхабад	I38	I2,6	СК	eP	04-04-55,5						+3,4
					MLg_1	I0-2I,5			I,I	3,5		
2I.	Кишенев	272	I2,9	СК-z	iP	04-05-0I,2						
				B	i	I3						
				CB	i(S)	07-23						
				B	i	52						
					LM	04-II,5	0,3	0,5	0,5	8,0	3,9Iмк	
22.	Боровое	6I	I5,I	СКМ	-iP	04-05-28,I	-0,002	-0,06	0,07	0,9		+3,[illegible]
				"загр	Pмах		0,II	0,23	0,29	0,9		
				СКМ	eS_E	08-I0,7						
				"	eLg_N	II-28,3						
				СКД	ML	I3	0,3	0,5	0,7	I2	3,99мк	
23.	Пулково	325	I5,6	СК	iP	04-05-36						+I,8
					i	44						
					M_I				0,3	I8		
					M_2				0,5	8	4,04мк	
					M_3				0,45	6		
24.	Межгорье		I5,85	СК-z	eP	04-05-44,I						
				Ez	eX	52,9						
25.	Чимкент		I5,6	СК	$-iP_2$	04-05-45						
26.	Львов	285	I5,8	ВЭГ-z	iP	04-05-37						+2,[illegible]
				СК-z	iX	47						
				" E	eLg_1	II-50						
				" E	eLg_2	I2-5I						
27.	Самарканд	II4	I6,I	СК	eP	04-05-43,0						+I,[illegible]
					i	50						
					MLR	I4		0,7	0,4	I2	3,78мк	
28.	Ташкент	I05	I6,6	СК	-eP	04-05-48,5						I2,[illegible]
						54,5						
29.	Ужгород	282	I7,0	СКМ-3	eP	04-05-53						+2,4
					Pмах				0,023	I,0		

I.07.68

I	2	3	4	5	6	7	8	9	I0	II	I2	I3
29.	Ужгород (прод)				i	04-05-56			+0,067	I,0		
					i	06-08			0,14	10		
30.	Душанбе		I7,4^x	СК	-iP	04-06-07,3						
					eLg	I2-44,8						
31.	Наманган		I7,75^x	СК	-iP	04-06-II,8						
32.	Гарм	II0	I8,6	СКМ	eP	04-06-I5						-4,3
33.	Андижан		I8,55^x	СК,СКМ	eP$_I$	04-06-I9						
				" Z	iP$_2$	22			0,9	I,5	5,70 MPV	
				" E	ML	I6-I6		I,0		II,0		
				" E	ML			I,5		9,0	4,63 ML	
34.	Фрунзе		I8,8^x	СКМ	eP	04-06-25						
				"	Pмах	29			0,I	I,0	5,0 MPV	
				СК	ML	I8	0,6			9,0	4,23 ML	
35.	Красногорка		I9,9^x	СК	iPz	04-06-38			-0,6	I,0	5,98 MP	
36.	Или		I9,95^x	СК	iP	04-06-38,2						
37.	Хорог	II2	20,2	СК-Z	P	04-06-36,0	+0,3	-0,4	-0,5	[illegible]	5,70 MPV	
38.	Нарын		20,5^x	СКМ-3$_E$	iP	04-06-43,4						
39.	Апатиты	344	20,9	СК	-iP	04-06-4I,3						-6,6
					eS	I0-33						
40.	Мургаб		20,9^x	СК	eP	04-06-47,6						
					eS	I0-43,7						
.	Рыбачье		20,9^x	СКМ-Z	iP	04-06-48						
42.	Талгар	92	2I,0	СК	+iP	04-06-44,0	-0,05	+0,09	+0,I9	II,2	MPV 5,25	+I,
					LM	I8	0,26	0,3	0,42	2,5		
43.	Курменты		2I,3^x	СК	iP	04-06-52	0,6	4,8	4,2			
44.	Пржевальск		2I,7^x	СК	iP	04-06-55,9						
45.	Новосибирск		22,3^x	СК	P	04-07-0I,3			0,3	I,8	5,42 MPV	
					S	II-37,4						
46.	Ельцовка	63	24,7	СКМ	iP	04-07-20,0			0,2I	0,8	5,76 MPV	+I,5
47.	Чаган-Узун		25,85^x	СКМ	-iP	04-07-37,4			0,I	I,0	5,45 MPV	
48.	Монды	63	33,8	СКМ-3	iP	04-08-II,6						
49.	Закаменск		35,I^x	СВКМ-3	+P	04-08-58,5			0,0I4	I,2	4,77 MPV	

I	2	3	4	5	6	7	8	9	I0	II	I2	I3
50.	Водайбо	50	39,6	СКМ-3	+iP	04-09-30,6			0,I3	0,9	5,86 mpv	+I,3
5I.	Тикси		4I,95^{x}	СКМ 3 СК,ВМЗ	+iP	04-09-56,0			+0,046	I,0	5,36 mpv	
52.	Тупик	53	43,8	СКМ	iP	04-I0-06,5	0,028		0,051	0,9	5,46 mpv	+2,8
53.	Якутск	40	45,7	СКМ-3	+iP	04-I0-20,0			0,092	0,8	5,86 mpv	+I,
54.	Владивосток	6I	56,2	СКМ	iP Pmax	04-I0-39,0	0,5		0,04			
55.	Ст. №2	55	52,7	СК	eP	04-II-14,0						+I,
56.	Иультин	I8	59,2	СКМ-3	iP	04-I2-0I,0	-0,043	+0,03I	+0,09	0,9	5,9 mpv	+0,
57.	Ю.Сахалинск		68,2^{x}	СКМ	iP	04-I3-06,3			0,08	I,5	5,67 mpv	

22.12.1971г. (Севернее Каспийского моря – АЗГИР) - Западный Казахстан
(07-00)

УSC: Н=06-59-56,6
φ =47,90°N
λ =48,07°E   h =0км
MB = 6,0

ЕССН: 0=06-59-55,56
φ =48,09° N
λ =48,18°E   h =0км
MPV = 4,3

Севернее Каспийского моря

1	2	3	4	5	6	7	8	9	10	11	12	13
№ пп	Станция	Az°	Δ°	Приб.	Фаза	Время	T сек	Aм NS	EW	Z мм	Mag	Res
1.	Махачкала		4,8^x	СХ-ВЗ	iP	07-01-15,7						
					(iS)	57						
					Smax		12	11	18	3		
					ℓM		6	12	12	3,5	4,2 ML	
2.	Пятигорск	223	5,4	СКМ-Z	iP	07-01-18,0						+1,3
				"	Pmax	21	1,5			3,67		
				СК-Z	Pmax	22	2,2			2,81		
				"NS	iS	46						
				SW	i	44	1,4			5,1		
				" Z	Smax	46	1,6			11,8	4,06 MS	
				"EW	i	03-00						
					i max	02	1,6	6,7	10,3	12,1		
				" Z	i	04-08						
				"	max	26	10			4,04		
				"EW	i	05-30						
					i max	07-06,6	8	0,9	1,45	1,7		
3.	Анапа		6,5^x	СКМ-Z	iP	07-01-39,0		+1,2	-3,5	+9		
				"	i	41,5						
				"E	iS	02-30,5						
				СД	ML	07-05,5	8,0	2,0	2,3	2	4,14 ML	
4.	Тбилиси	201	6,8	СК-Z	eP	07-01 39						+2,2
				"E	e	02-36						
				" NZ	ML	07-50	8,0	1,5		2,3	4,08 ML	
5.	Зугдици		6,8^x	СВХ	-iP	07-01-44						
					Pmax		0,5			3,0		
6.	Абастумани		7,0^x	СКМЗ-Z	+iP	07-01-45,8	0,6			1,36		
				N	e	02-17,8	1,0	0,9				
				"	"Smax	25						

22.12.71

1	2	3	4	5	6	7	8	9	10	11	12	13
7.	Шемаха		$7,0^x$	СХ-N	iP	07-01-47						
				"	iX	02-02		1,8	1,5			
8.	Бакуриани	209	7,2	СКМЗ-Z	+iP	07-01-42,5	1,4			1,0		+1,2
				СКД	P		0,8			0,04		
				"	i	02-19,5	1,0			0,88		
				"	iS	03-19,6	1,0			2,35		
				"	i	04-07,5	1,2			1,5		
				" N	L	05-3	14	4,14				
				" Z	ML	05.7	12			7,82	4,14 ML	
9.	Кировабад		$7,1^x$	СКМ-Z	iP	07-01-48						
				"c	iX	02-24						
				"	Pм		0,6	0,51	0,67	0,7		
				"	Sм		1,0	0,86	1,1	0,45		
10.	Сочи	235	7,4	СК-В	iP	07-01-47						+0,9
				СКМ-В	iP	47,0	0,5	-1,2	-1,2	+3,0		
				"	Pmax	50	0,5			2,8		
				"E	i	02-26,5						
				СД-В	iP	01-47						
				"	Pmax	50	0,6			2,6	3,7	
				с-у	i	02-21						
				СД-Е	i	25						
				СД	iSmax	37	2,0	2,5	4,0		3,7	
				СКМ-Е	i	27						
				СД	ML	05-22	14	1,5	1,3	2,0	3,0 ML	
11.	Баку		$7,4^x$	СК	iP	07-01-52						
					i	02-36						
					iZ	39,0	4,0					
					iE	05-47						
					ML	08-47	10	5,2	2,0			
12.	Ереван		$7,8^x$	СК-Z	eP	07-01-58						
				"EN	i	04-24						
					ML	09	7,0	1,25	1,13		4,5	+3,5
13.	Горис	189	8,7	СК	-iP	07-02-02						
14.	Ленкорань		$8,9^x$	СХ	ePM	07-0?-13,5	6,0	0,8	0,75	1,5	4,26	

I	2	3	4	5	6	7	8	9	I0	II	I2	I3
I5.	Алушта		9,6[x]	СХ-z	-iP	07-02-22						
				"	Pmax	24	0,7			I,4		
				"	e	33						
				"z ,с	e S	04-06						
I6.	Ст. №I		9,6									
I7.	Ялта		9,8[x]	СК-z	iP	07-02-24,8						
				,с,в	Pм	25,8	0,6	0,8	0,6	I,5		
				"с,в	S	04-13,6						
I8.	Москва	323	I0,0	СВХ	eP	07-02-24						
				СВК	e	30						
				СДХ	e	36						
				СДК	e	46						
				СДХ	e	52						
				СВК	e	03-I8						
				СГК	e S	04-40						
				"	e	4I						
				"	e Lg	05-I6						
				"	e	40						
				"	e	48						
				СВКД	M L	07-07,3	I4			2,3	4,I5 ML	
I9.	Обнинск	3I8	I0,I	БФ-z	+iP	07-02-23,6	I,0		I,8			+0,9
				СК-вз	i(S)	04-40						
				"сю	i(SS)	55						
				"z	L max	07-40	I0	4,2	3,5	3,6	4,48 ML	
				ПЮ-z			I0	8,0	3,6	3,0	4,4I ML	
				СКД-z			I0	3,4	3,7	3,5	4,48 ML	
20.	Симферо-поль	257	I0,2	СХ-св	eP	07-02-24						+2,2
				с	e(S)	04-I9						
					S м	20,0	0,9	0,73			4,0 MS	
					S M		I,0		0,42			
2I.	Кизыл-Арват	I43	I0,6	СК-z	eP$_I$	07-02-30						+2,3
				"	e$_2$	34						
				" N	e$_3$	38						
				"	i$_1$	53						
				"	e$_4$	03-35						

I	2	3	4	5	6	7	8	9	I0	II	I2	I3
22.	Сверд-ловск	36	II,6	СКМ3	iP	07-02-43,0						+I,9
				"	Pmax	46,0	I,0			I,2		
				СГ	LM	07-09	II	I,2	I,5	4		
23.	Ашхабад		I2,0^{x}	СКМ3-Z	eP	07-02-55						
24.	Ванновская	I40	I2,5	СКМ-3	eP	07-02-52						+4,9
25.	Черновицы		I4,3^{x}	СКД,СХ	iP	07-03-26,0		-2,0				
				СХ				+2,0	+2,0			
				СКД			I,2	I,8				
				СХ			I,0		6,4			
				СКД,СХ	i	03-34						
				СКД	SP	59						
				СХ	SP	04-0I						
				СКД	i	I5						
				"	S	05-29		+2,0				
				СХ					+2,5			
				СКД			I,4	2,5				
				СХ			I,2		2,7			
				СХ	sS	06-05						
26.	Кишенев	272	I3,I	СК- ,В	eP	07-03-03,0	I,5			I,I		+2,9
				"	i	I5						
				"с	i	08-I8						
				"в	i	27						
				СД-Z	ML	07-09,3	I3			I,7	4,25	
27.	Боровое	62	I4,9	СКМ	+iP	07-03-26,2	0,9	+0,0I	0,05	+0,04		+0,4
					Pmax	30	0,9	0,20	0,3I	0,786		
					eS	05-28,5						
					e	06-06,2						
28.	Пулково		I5,2^{x}	СГ	iP	07-03-38						
					i max	40				I,5		
					i	45						
					i max	47	I,8			2,9		
					e(S)	06-32						
				СГ	LM	II,5	8,0	I,I	I,I		4,5 ML	
				СКМ	LM	II,5	8,0	I,I	I,I		4,5 ML	

I	2	3	4	5	6	7	8	9	I0	II	I2	I3
29.	Львов		I5,3^x	СКД-Z	iP	07-03-39						
				"	e	47						
				"	i	06-2I						
				"	e	29						
				"	ML	07-II,6						
30.	Самарканд	II5	I5,9	СК	eP	07-03-40						+2,6
3I.	Межгорье		I5,9^x	СКМ3-Z	eP	07-03-46,7						
				Z	e	53,7						
				N	i	06-55,7						
32.	Ужгород	28I	I7,2	СКМ	iP	07-03-52,7	I,0			+0,0I2		+3,6
				"	iX	58,2						
				"	Pmax	04-00	I,I	0,03	0,07	0,I5		
				"	i	03						
				"	i max	I5	I,I	0,07	0,I6	0,34		
				"	i	07-36						
				"	i	09-4I						
33.	Душанбе	II4	I7,7	СК	+iP	07-04-05				I,5	4,6	
					eS	07-30	9,0					
34.	Гарм		I8,0^x	СКМ3-Z	+iP	07-04-I3,I	0,9			0,47		
				"	i	23,3	I,0			0,625		
				E	i	05-42	I,3			0,225		
				СК-Z	iP	07-04-I3,I	I,8			0,8		
				N	i	05-59	3,2			0,4		
				N	iL	07-44,3	6,4			0,88	4,5I мк	
35.	Фергана		I8,I^x	СКМ3,СК-Z	+eP	07-04-I4,3						
				СК-Z	MP	I5,3	I,0			0,6		
				"E	e	09-40,3	8		I,5			
				"	ML	07-I3	II		4,5	5,5	5,09 мк	
36.	Андижан		I8,3^x	СКМ3-Z	-iP	07-04-I7,0	0,6			0,I		
					MP	20	I			0,9		
				СК-Z	MP	20	I,5			2,I		
				"E	eS	08-3I						
				" N	e Lg	I0-07						
				" "	M	07-I5	8,0		4,0	3,0	4,98 мк	

I	2	3	4	5	6	7	8	9	I0	II	I2	I3
37.	Фрунзе	96	I9,2	СКМ	iP	07-04-23,5						-0,I
					i	27,5						
				"	MP	29,0	0,8			0,22		
				СКД	M L	I4-20	I0		I,5		4,58 мк	
38.	Хорог	II3	20,I	СК-z	P	07-04-33,7						+0,6
39.	Талгар	92	20,8	СКМЗ	iP	07-04-42,7	I,I	0,II	0,I7	+0,62		+I,0
40.	Мургаб		20,8ˣ	СК	iP	07-04-45,I	0,6	-0,5	+0,8	+0,8		
					eS	08-4I,I						
4I.	Апатиты	344	20,9	СКМ,СХ	iP	07-04-42,6						+0,5
				"	i	43,3						
				СКМ-z	Pmax	45,0	I,0			I,3		
				СХ	iS	08-27,8						
42.	Пржевальск	93	2I,9	СКМ	eP	07-04-54						+I,9
43.	Новосибирск		22,6ˣ	СКМ-z	+iP	07-05-03,0	I,4			0,05		
					Pmax	05,5						
					i	06-0I						
44.	Ельцовка	63	24,5	СКМЗ-z	iP	07-05-I9,I	I,0	+0,2I	-0,07	+0,65		+I,9
45.	Усть-Элегест		29,2ˣ	СКМЗ-z	iP	07-06-05,2						
					Pmax	07,0	I,2			0,2		
46.	Хейс	3	32,8	СК	+iP	07-06-36						+3,I
					i Pmax	37	I,0			0,I2		
47.	Монды	63	33,6	СКМ	+ P	07-06-43						+3,3
48.	Иркутск	6I	35,4	СКМЗ	+eP	07 06-57						+I,7
					PM	58						
					eLR	I2,5						
49.	Закаменск	65	35,4	СКМ	+iP	07-06-58,4	I,2	+0,026	+0,034	+0,02I		+3.
				"	PMI	07-00	I,2		0,I07			
				СКД	L	22-36,6					5,0мк	
				"	LM	23-36,2	I6			0,673		
50.	Бодайбо	50	39,4	СКМ-3	+iP	07-07-29,5						+0,9
					Pmax	30,0	I,0	0,58	0,47	0,65		

I	2	3	4	5	6	7	8	9	I0	II	I2	I3
5I.	Тикси	27	42,4	СК,СКМ	iP	07-07-56						+2,4
				СКМ-Z	Pmax	58,0	I,I			0,I7		
				СВК, СКМ	i	09-39						
				ГК	e	46						
				СГК	Mi	3I,8	I4		0,3			
							I0	0,I				
52.	Тупик		43,4^x	СКМ	+iP	07-08-05,7	0,8	0,05	0,06	0,25		
53.	Якутск		45,I^x	СК	iP	07-08-20,0	I,0			+0,I5		
					Pmax	22	I,0			0,32		
					i	I0-I4						
5´	Ст №2 (Кульдур)		52,I^x	УСФ	i	07-I0-I2						
55.	Сеймчан		54,0^x	СКМ	P	07-09-27,6						
				"	Pmax	28,6	I,I			0,26		
				"Н	MP		I,2	0,06				
							I,3		0,09			
56.	Владивосток	6I	56,0	СКМ,СК	eP	07-09-39,5	I,0			0,I2		+I,
				СК			5,0			0,3		
57.	Иультин	I8	59,I	СКМ-Z	P	07-I0-0I,I		-I,2	+0,6	+3,5		+0,
				" Z	Pmax	02,0	I,0	0,069	0,05	0,23		
				"E	i	06						
				" N	i	I6						
58.	Ю. Сахалинск	52	59,7	СКМЗ-Z	eP	07-I0-06,4						+2,
				" Z	Pmax	08						
				"E	e	II						
				" Z	e	20,4						
				" Z	e	53						
				" Z	e	I2-I8,8						
59.	Мирный		II9^x	СКМ	ePKP	07-I8-47						
60.	Новолазаревская		I27^x	СКМ	iPKP	07-I9-03	I,0			0,02		
					i	09						
					e	23						

29 (July) июля 1976г. (АЗГИР) Севернее Каспийского моря (05-00)

ЕССН-04-59-56

φ=48,1 N λ=48,2 E h=0 км

$M_p^{СКМ}$=5,9 (11ст) M=4,5 (3ст)

~~Севернее Каспийского моря~~

USC: H=04-59-58,0

φ=47,81 N

λ=48,10 E h=0км

MB=5,9

№пп	Станция	Δ° по Обнинску (Δ°-по годогр.)	Приб.	Фаза	Время	T сек	A μ NS	A μ EW	A μ Z	Mag MP	Mag ML
1	2	3	4	5	6	7	8	9	10	11	12
1.	Махачкала	5.1	СКМ	+iP	05-01-16.3						
			СК	Pmax	22,0	0.7	11.0	5.5	5.5		
			"	iS	45.0						
			"	Smax	49.0	0.6	17.0	8.7	4.6		
2.	Пятигорск	5.4	СК	eP	05-01-19						
				Pmax	20.0	2.0			4.5		
				eS	01-43						
				Smax	47	2.0	6.5				
				i	51						
3.	Тбилиси	6.8	СКМ	P	05-01-39						
				Pmax	01-40						
4.	Грозный	4.8x	СКМ	-iP	05-01-15.8		+0.7	+0.2	-3.4		
				Pmax	17.0				4.3		
				iS	42						
				Smax	44	1.0	7.1	3.0			
				ML	02-07		7.8	4.4			4.4
5.	Бакуриани	7.2	СКМ	iP	05-01-49.6						
			"	Pmax	45.6	1.0			0.68		
			СКД	ML	05-05,5	12		4.6			
			"	ML	05,8	11	3.2				
6.	Сочи	7.4	СКМ	iP	05-01-49				1.6		
			СКД	i(S)	02-25			2.5			

1	2	3	4	5	6	7	8	9	10	11	12
7.	Кировабад	7.6	СКМ	-iP	05-01-47						
				Pmax		1.0			0.50		
				i	02-14						
				i	02-54						
8.	Баку	7.8	СК	iP	05-01-54						
				i	01-55						
				i	02-00						
				i	02-12						
9.	Ленинакан	7.9	СКД	eP	05-01-57						
10.	Ереван	8.3	СК	iP	05-01-59.0						
			"	i	02-40						
			"	i	05-01						
11.	Горис	8.7	ВЭГ	+iP	05-02-04						
				i	02-17.6						
				i	26.2						
				e	33.2						
				eS	46.2	1.2	1.05				
12.	Симферополь	10.2	СК	-eP	05-02-25.0						
			СХ	e	26						
			СХ	Pmax	27.0	0.4			0.5		
			СК	e	43						
			"СХ	eS	04-20						
			СК	Smax	04-	1.0	1.0	0.6			
			СХ	Smax	04-23	1.0	0.4	0.6			
			СК	e	04-43						
			"	eL	06.3						
			СКД	ML	08-09	14			1.0		3.8
			СК	ML	08-34	10	0.3	0.7			4.0
13.	Обнинск	10.1	ЭН-1	eP	05-02-28						
			"	Pmax	32.0	1.0					
			(ГИСО) ГИП-1	eS	04-24						
			ЧИСО	M	07-50						
14.	Арти	10.5	СКМ-3	eP	05-02-30						
			"	e	02-50						
			СКД	eS	04-26						
			СКД	M	08-11	12	1.0	1.5	2.0		4.1

29.УП.76

I	2	3	4	5	6	7	8	9	I0	II	I2
15.	Кизыл-Арват	10.8	СК	eP	05-02-32						
16.	Ашхабад	12.6	СКМ-3	eP	05-02-55.2						
				i	02-57,2						
			СК	e(S)	05-05.0	1.0		1.0			
				ML	13-39.1	9.0			1.2		
17.	Кишенев	13.1	СК	-iP	05-03-04						
				Pmax	05.0	1.0		0.9	1.1		
				i	18						
				i	03-36						
				i	04-16						
				i	05-18						
				iS	38						
				iSmax	44						
			СД-1	ML	09-42	11			1.9		4.5
			СК	ML	09-46	10		1.5	1.8		
18.	Минск	13.7[x]	СК	eP	05-03-18						
			СД-1	eL	09,4						
			"	ML	10-59.0	12		2.0			
19.	Пулково	15.7	ВЭГ	+iP	05-03-38.5						
			"	Pmax	03-48.0	1.3			1.2		
				e	47						
			СГ	e(S)	06-27						
			СД-1	ML	11-16	9.0	0.9				4.3
			СГ	ML	11-18	10	0.8	0.5	1.5		4.2
						10		0.6	1.2		
16	[illegible]	15.9	ск	iP	05-03-40.5						
20.	Львов	15.9	СКД	P	05-03-40						
					49						
					04-18						
				e	05-50						
				e	07-06						
				M	11-47.0	9.0			1.0		
21.	Ташкент	16.4	СКМ	-iP	05-03-48						
			"	Pmax	49,5	1.0			1.1	6.0	
			СК	Pmax	49,5	1.5			1.2	5.9	
			СК	i	05-53.5						
			"	imax	55.5	2.0			3.0		
			СКМ	imax		1.2			2.8		
			СК	ML	05-12-34	10	1.5	3.0	1.7		5.[illegible]

1	2	3	4	5	6	7	8	9	10	11	12
22.	Ужгород	17.2	СКМ	–iP	05–03–55.5						
				Pmax	56.0	0.9			0.350		
				+i	03–58.5						
				Pmax	04–03.0	1.0			0.5		
				i	04–08						
				i	15						
				i	30						
				i	37						
				i	44						
				i	55						
				e	05–53						
23.	Душанбе	17.7	СХ	+iP	05–04–06						
24.	Андижан	18.7	СКМ	eP	05–04–18						
			СК	Pmax	22.0	1.4			1.6		
			СКМ	Pmax	23.2	1.3			1.43		
			СК	i	05–32	1.2		1.0			
			"	e	09–07	4.0	1.0				
				ML	14–06	10	2.0	2.2			
			"	ML	16–30	9.0	2.2	3.5	2.2		
25.	Куляб	18.7	СК	+iP	05–04–18.4						
				Pmax	21.4	1.0			1.3	6.8	
				eS	10–45.4						
26.	Фрунзе	19.2	СКМ	eP	05–04–24						
				i	04–28						
				Pmax	30.0	1.0			0.26	6.4	
				i	42						
				i	48						
			СКД	e	05–08						
			СКД	e	05–22						
				e	06–28						
				e	07–08						
				e	07–50						
				e	08–10						
				e	08–40						
				e	09–14						
				e	10–14						
				e(S)	11–18						
				MLR	17–00	8.0	1.8				5.5

29.УП.76

1	2	3	4	5	6	7	8	9	10	11	12
27.	Хорог	20.1	СК	P	05-04-35						
28.	Нарын	20.7	СКМ-3	+eP	05-04-42						
				e	05-31.5						
29.	Талгар	20.8	СКМ	+iP	05-04-43.0	1.2	0.11	0.2	0.26	5.5	
			"	iP_{max_1}	45	1.1			0.52	5.8	
			"	iP_{max_2}	48	1.2			0.77	6.0	
			СК	eP	43	2.2			1.0	5.8	
			"	S	08-49.0	8.0			3.0		4.7
			"	iL_R	13-39	17	0.5		0.7		
			"	ML	05-15	11	0.5	0.1	0.8		4.5
30.	Пржевальск	21.9	СКМ	+iP	05-04-55						
			"	P_{max}	59.0	1.0			0.20	5.5	
31.	Новосибирск	22.7x	СКМ-3	+iP	05-05-03.5						
			"	P_{max}	04.7	1.4			0.454	5.7	
			"	iS	09-10.3						
			СД-1	e	10-28.6						
			"	e	58-45.4						
32.	Норильск	28.7x	СКМ	+iP	05-06-01						
				P_{max}	02.0	1.0			0.104		
				i	06-21.5						
				i	06-38						
				i	07-19.5						
				i	07-56.5						
				e	11-58						
				M	20.5	16.0		0.3			
33.	Усть-Элегест	29.3x	СКМ-3	-iP	05-06-05.5	1.0	+0.04	-0.03	-0.09	5.8	
				iS	13-10.5						
34.	Иркутск	35.4	СКМ	+ P	05-06-58.2						
			"	P_{max}	59.2	1.0	0.066	0.154	0.186	6.0	
			"	Lg	10.5						
			СКМ	Max	10-45.7	1.9		0.142			
			СКД	eL_R	11.9						
			СКД	ML	12-15.0	8.0	0.38	0.34	0.56		4.6
				eL	22.5						

1	2	3	4	5	6	7	8	9	10	11	12
35.	Закаменск	35.4	СКМ	+iP	05-07-00.4	0.8	-0.4	+1.0	+1.7		
			″	P_{max}	01.4	1.0			0.07		
			СКД	e	08-12.4						
			″	e	10-05.2						
			″	L	11-12.4						
				ML	11-35.8	8.0	0.49	0.62	0.69		4.2
36.	Тикси	42.3[x]	СКМ	+iP	05-07-57.0						
			″	P_{max}	58.0	1.0			0.09	5.6	
			СК	P_{max}	58.0	1.5			0.2	5.8	
			СКМ-3	i	08-02.5						
			″	i	30						
				i	35.5						
				i	40.5						
				i	51.5						
			СК	e	09-39.5						
			″	e(S)	14-00						
			″	e	19-31						
			″	e	59						
			″	ML	30-20.0	14		0.2			4.2
						12	0.2				
38.	Тупик	43.5	СКМ	-iP	05-08-05.9	2.0	0.072	0.113	0.220		
39.	Якутск	45.5	СКМ	eP	05-08-13.6						
40.	Сеймчан	54.3	СКМ	+iP	05-09-28.5						
				P_{max}	29.8	1.0			0.17	6.1	
				i	10-32.1						
41.	Монды	55.3	СКМ	+ P	05-09-36						
				P_{max}		1.0			0.07	5.7	
				e	09-58						
				e	14-00						
			СКД	ML	37-16	18			0.5		4.6
4[illegible].	Магадан	55.1[x]	СКМ	+P	05-09-36						
			″	P_{max}	38.0	1.0			0.07		
			″	e	58.5						
			СКД	e	14-00						
			″	e	15-16						
			″	ML	37-16	18			0.5		

1	2	3	4	5	6	7	8	9	10	11	12
43.	Пулково	59.1	СКМ	+iP	05-10-02.5						
			•	Pmax		1.0	0.054	0.046	0.17	6.1	
				i	10-13						
				i	25						
				i	54						
				i	11-14						
				•	11-48						
				•	12-10						
				i	31						
			СКД	eS	18-08						
			•	•	21-24						
			•	•	26-08						
44.	Ю.Сахалинск	59.7	СКМ	+iP	05-10-07.3						
				Pmax	08.1	1.0			0.19	6.2	
				e	10-16.1						
				e	10-29						
				e	10-49.7						
				e	12-19						
45.	Новолазаревская	121.4	СКМ	ePKiKP	05-18-51.5	Отключение	из	с/басс.			
46.	Ст.№ I (Михнево)	9.4[x]	СКМ	-eP	05-02-I6						
47.	Анапа	8.I[x]	СКД	P	05-0I-58	0.5	I.0	I.0			
				eS	02-II						
				ML	07.8	9.0	I.5	I.3	2.0		4.0
48.	Ельцовка	24.5[x]	СКМ	iP	05-05-I9.8						
				Pmax	29.3	I.2	0,I00	0.400	0.376		
49.	Апатиты	I5.8[x]	СКМ	P	05-03-44						
			СКД	eS	07-33						
				ML	05-I3.2	I2.0	I.4	I.0	I.8		ML 4,5 MLH 4,7
50	Шеки	6.7[x]	СКМ	+iP L	05-0I-40.5						
52.	Степанован	7.3[x]	СКМ	iP	05-0I-48.2						
53.	Наманган	I8.8[x]	СК	-iP	05-04-2I						
5I.	Алушта	9.8[x]	СХ	iP	05-02-23.6	0.6			0.I6		
				Pmax	24.6	0.6			0.78		
			СК	ML	05-08.4	I6.0			0.7		

Sept.
30 сентября 1977 (АЗГИР) Севернее Каспийского моря -
(07-00) Западный Казахстан

JSC: H=06-59-55,9
φ =47°,85 N
λ =48°,13 E h =0км
MB=5,0

ECC: H 0-06-59-59,8
φ =47,92 N
λ =48,31E
h =0
MPV (A) = 5,0 (9 ст)
Севернее Каспийского моря

№ пп	Станция	Δ°	Az°	Приб	Фаза	Время	T сек	A NS	A EW	A Z	Mag	Res
1	2	3	4	5	6	7	8	9	10	11	12	13
1.	Махачкала	5.04	186	СКМ3	+iP	07-01-15.0						
					eS	02-24						
					ML	04-10.0	14.0	1.0	0.9	0.6	3.1 3.5	
2.	Пятигорск	5.36	224	СКМ	eP	07-01-18.8						
					iS	01-43.6						
3.	Белый уголь	5.1^x		ВЭГ	+iPz	07-01-18.9	0.2	0.02	0.04	0.10		
					Pmax	20.5	0.2	0.58	0.53	0.66		
					+i	01-24.2						
					+iS	01-39.1						
					Smax	01-46.5	1.0	0.5	0.18	0.10		
4.	Зугдиди	6.0^x		СК-Z	eP	07-01-32						
.	Тбилиси	6.3^x		СК	eP	07-01-37						
					ePPP	02-09						
					eS	03-15						
					eSS	03-59						
6.	Абастумани	7.0^x		СКМ-Z E	eP	07-01-45.6						
					eP'	02-23						
7.	Сочи	7.42	236	СКМ	+iP	07-01-46.1						
					i	01-58.4						
					i	04-21.8						
					e	04-59.0						
8.	Степанован	7.0^x		СКМ-Z	iP	07-01-47						
					i	02-18.4						
					i	30.6						
					i	44						
9.	Ленинакан	7.87	205	СКД	eP	07-02-23						

30.IX.77

1	2	3	4	5	6	7	8	9	10	11	12	13
10.	Горис	8.57	190	ВЗГ	−iP	07-02-02.0	0.8			-0.2		
				"	i	02-15						
				СХ	e	04-06						
				"	eS	04-40						
11.	Москва	10.19	323	СХ	eP	07-02-12						
				"	e	02-35						
					e	03-05						
12.	Ст. № 1 (Михнево)	9.0x		СКМ	−iP	07-02-15.2	0.4			0.315		
13.	Алушта	9.6x		СХ-	+eP	07-02-22						
					Pmax	26.0	0.5			0.07		
				"	e	02-38						
				"в	e	02-55						
				"	e(S)	04-09						
14.	Обнинск	10.21	318	СКМ	+iP	07-02-26.1						
					Pmax	30.0	0.8			0.15		
					e	03-05						
					e	04-20						
					e	05-12						
				СКД	ei	08-02-30.0	24.0					
15.	Арти	10.55	32	СКМ	eP	07-02-28.7						
					e	02-31.5						
					eS	04-27.7						
				СКД	e	07.6						
16.	Свердловск	11.63	35	СКМ-3	+iP	07-02-43.0						
					Pmax	45.3	1.0			0.12	5.5	
					e	02-58						
					e	03-05						
					e	03-20						
					e	04-52						
17.	Ашхабад-2	12-48	140	СК	P	07-02-47.3						
				СКМ	−imax	03-06.6	0.6			0.09		
				"	+iSmax	05-14.3	1.3	0.19				
				СК	+i	06-22.6						

30.IX.77

I	2	3	4	5	6	7	8	9	I0	II	I2	I3
18.	Боровое	14.86	61	СКМ	P	07-03-26.4	0.7			0.015	4.8	
19.	Самарканд	15.1^x		СК	eP	07-03-36.0						
					e	40.6						
					-i	46.8	0.6			0.4		
					e(S)	06-49						
					Mi	12,59	6.0		0.4		4.2 Ml	
							8.0			0.4		
20.	Ташкент-2	16.34	105	СКМ3	eP	07-03-44.0						
				"	Pmax	53.5	1.2	0.1	0.2	0.3	5.9	
				СК	e	09-13.5						
					e	10-09.5						
					e	12-00						
					ei	08-17-50						
21.	Ужгород	17.28	221	СКК	eP	07-03-58.5						
					Pmax	04-03.5	0.8			0.015	4.8	
					i	04-08						
					i	04-13						
					i PP	06-40						
					i	07-10						
					e	08-10						
					e	12-25						
					e	20-20						
					Mi		18.0			1.1	5.6 Ml	
22.	Душанбе	17.59	114	СК	eP	07-04-04						
23.	Гарм	18.28	11	СКМ	iP	07-04-12.2						
					Pmax	12.2	1.2			0.08	5.3	
24.	Фергана	18.0^x		СКМ	eP	07-04-13.7						
				СК	i	12-						
25.	Куляб	18.59	114	СК	eP	07-04-16						
					eS	10-47						
26.	Андижан	18.62	103	СКМ	eP	07-04-16.4						
				"	Pmax	19.8	1.0			0.15	5.6	
				СК	Pmax	20.0	1.0			0.2	5.7	
					i	05-07						
					e	08-16						
					ei	13-30						
					Mi	14-00	13		0.7	0.8		

30.IX.77

1	2	3	4	5	6	7	8	9	10	11	12	13
27.	Фрунзе	18.7[x]		СКМ-2	eP	07-04-22						
					e	04-26						
					eS	04-50						
					Smax	04-54.0	0.8	0.04				
28.	Хорог	19.97	113	СК	eP	07-04-33						
29.	Талгар	20.73	92	СКМ	+iP	07-04-41.0						
					Pmax		1.2	0.009	0.009	0.033		
					Pmax1	43.0	1.5	0.031	0.023	0.076	4.9	
					Pmax2	42.0	1.5	0.053	0.039	0.083	5.0	
30.	Новосибирск	22.4[x]		СКМ3	+iP	07-05-01.3						
					Pmax	03.3	1.4	0.02	0.026	0.056		
					e	08-52.3						
					i	09-08						
				СД-1	Mle	16-35.0	12.0			0.6		
31.	Апатиты	21.06	344	СКМ	+iP	07-05-46.0						
					Pmax	06-01 48.0	1.0	0.13	0.1	0.16	54	
				СД-1	eL	08-01.5	28			1.5		
32.	Ельцовка	24.47	63	СКМ	+iP	07-05-18.6						
					Pmax	18.6	1.0			0.100	5.3	
					eS	09-43						
33.	Норильск	28.93	27	СКМ	eP	07-05-59.						
					Pmax		1.4			0.017	4.7	
					e	06-35						
					e	06-38						
					e	06-47						
					e	06-59						
					e	07-17						
					e	07-28						
					e	08-03.0	2.1			0.5		

30.1X.77

1	2	3	4	5	6	7	8	9	10	11	12	13
34.	Монды	33.60	63	СКМ	+eP	07-06-41.8						
					Pmax	42.9	1.2			0.035	5.2	
35.	Закаменск	35.35	65	СКМ	+iP	07-06-57.1						
					Pmax		1.3			0.013	4.7	
					eP	09-25.4						
					Pmax		1.2			0.01	4.4	
36.	Бодайбо	39.36	50	СКМ	+iP	07-07-29.0						
					Pmax	29.0	0.6	0.02	0.033	0.08	5.8	
37.	Иультин	59.23	18	СКМ	eP	07-10-00.5						
					e	10-39						

17 октября 1976 (АЗМР) Севернее Каспийского моря
(05-00)

Западный Казахстан

ЕССН: 0-04-59-55,0 ±2,0 s

φ = 47°,94 N

λ = 48°,04 E h = 0 км

MPV(A) сплс = 6,0 (по 22 ст)

MPV(B) ск = 6,5 (по 22 ст)

MLH (B) ск = 4,7 (по 8 ст)

MLV(B) ск = 4,5 (по 8 ст)

MLC (C) скд = 4,6 (по 4 ст)

Северное Каспийского моря.

УSC: H=04-59-56,6

φ = 47°,81 N

λ = 48°,09 E h = 0 км

MB=5,8

№ пп Станция	Приб.	Фаза	Время	T сек	A мк NS	EW	Z	Mag	Δ°	Az°	Res S
1 2	3	4	5	6	7	8	9	10	11	12	13
1. Махачкала	СК	+iP	05-01-15.0	0.4	-3.0	+0.8			5.00	184	1.8
		Pmax	24.0	0.6	22.0	9.2	9.0	7.4			
		eSM	02-12	1.0	35.0	12.0	5.0				-0.7
		LM	06-00	8.0	4.9	4.3	4.5	4.3 MLH 4.2 MLV			
2. Пятигорск	СК	iP	05-01-17.5						5.23	223	1.1
		Pmax	18.5	2.0			4.0				
		i	01-30								
		i	01-44								
		Smax	01-46.0	2.0		6.0					
		i	04-24	9.0		5.0					
3. Зугдиди	СК	+iP	05-01-43						6.8x		
		Pmax		1.0			5.0				
4. Абастумани	СКМ	+iP	05-01-45.6						7.0x		
		iS	02-19.0	0.5	0.67						
5. Степанован	СКМ3	+iP	05-01-46.8						7.0x		
	СКД	i	02-37.2								
		i	03-45.8								
	Е	i	03-40.6								
		i	04-07.8								
		i	04-15.4								
		i	05-00.2								
6. Баку	СК	+iP	05-01-53						7.5x		
		i	01-54	0.5			1.5				
		e	02-36	20		90					

1	2	3	4	5	6	7	8	9	10	11	12	13
7.	Ленинакан	СКД	+iP	05-01-53.0	2.0			1.0		7.78	204	0.7
			e	02-34								
		ВЭГ	e	02-49.0	2.0	8.0						
		СКД	Mi	05-00	3.0	8.0	6.0		5.0			
8.	Ереван	СК	+iP	05-01-58.0						8.16	199	0.3
			i	02-10.5								
			i	04-35.5								
			i	05-38								
9.	Горис	СК	+iP	05-02-02.6						8.52	188	-0.1
		ВЭГ	Pмах	03.8	0.6			0.66	6.3			
		СК	e	04-33.8								
		СК	e	05-05								
10.	Ст. № 1 (Михнево)	СКМ	+iP	05-02-15.7	0.6			1.080		9.1^x		
11.	Симферополь	СКД	eP	05-02-21						10.06	257	-3.0
			eS	04-17								-2.0
		СКД	iM	07-21.0	17	0.5	0.6	0.6	3.6 ML 3.5 ML			
		СД-1	iM	07-25.0	16	0.3	0.6	0.7	3.6 ML			
12.	Алушта	СХ	eP	05-02-21.7						9.5^x		
			-iP	02-22.7	1.0			0.35				
			Pмах	23.2	0.6			0.57				
			i	02-38.6								
			e	03-38								
			e(S)	04-11								
		СК	iM	05-07.7	9.0			0.5	3.7 ML			
13.	Москва	СХ	eP	05-02-23.0						10.11	324	-1.6
			e	02-31								
			e	02-46								
			e	03-00								
			e	03-16								
			e	04-17								-3.1
			e	04-46								
			P	05-01								3.7
14.	Ялта	СХ	-P	05-02-24.2	0.7	0.3	0.3	0.8		9.7^x		
			e	04-05								
			e	04-14								
15.	Обнинск	СКМ3	+ P	05-02-25.0						10.12	319	0.3
			Pмах	28.0	1.0	1.1	1.1	1.3	6.5			
		СК	e	03-22								

I	2	3	4	5	6	7	8	9	10	11	12	13
продолж.												
	15.Обнинск	СК	e	05-04-06.0								
		СК	iM	07-50.0	8.0	1.5	2.5	2.1	4.5 4.3			
		НО	iM	50.0	10	1.3	2.0	1.9	5.5 5.6			
	16.Арти	СКМ3	-eP	05-02-28.8						10.66	38	-3.2
			Pmax	31.9	0.9			0.35	5.9			
			i	02-33.5								
			e	02-37.3								
			e	02-39.8								
			iM	08-05.0	11	2.0	2.5	2.5	4.4			
			iM		12			2.0	4.2 4.1			
			iM		7.0	1.0		1.3	4.3			
			iM		8.0		1.0		4.1			
	17.Кизыл-Арват	СК	eP	05-02-24.0						10.78	143	-9.1
			e	02-32								
			e	03-33								
			e	03-35.5								
	18.Свердловск	СКМ3	+iP	05-02-44.2						11.75	36	-2.7
			Pmax	47.0	1.0			1.0	6.4			
			e	03-18								
			e	03-32								
		СКД	e	04-50								
		СКД	e	06-04								
		"	iM	09-00.0	12	1.1	1.5	3.5	4.2 4.5			
	19.Ашхабад	СК	P	05-02-53.5						12.57	139	-4.6
			i	03-14								
			e	03-34								
			e	03-55								
			e	04-14								
			i	05-40.0	1.0			0.6				
			i	06-26								
			i	06-31.0	5.0			1.0				
			i	07-17	2.0			1.2				
			e	07-27.2	1.0			0.7				
			e	08-02	3.0			3.5				
			iM	09-55	8.0			2.5	4.6			
			iM	09-56	11			3.0	4.5			
			iM	10-04	9.0			3.0	4.6			

1	2	3	4	5	6	7	8	9	10	11	12	13
20.	[illegible]	СКД	-iP	05-03-02.0						13.04	272	-2.3
			Pмах	03.0	0.8			0.7	6.4			
		СКД	i	03-03.5								
			i	03-10								
			e	05-08								
			e	05-20								
			i	05-22								
			iS	05-28.0								-3.5
			iS	05-34								2.5
			iS P	06-18								2.6
			i	06-46								
			i	07-15								
			i	07-22								
			ML	09-42.0	10			1.4	4.3			
			ML	09-45	10	2.0	1.1		4.5			
		СД-1	ML	09-50	14			1.6	4.2			
21.	Минск	СК	e(P)	05-03-16						13.5^x		
			eS	07-45								
			eLe	08.9								
		СД-1	ML	09-58	12	1.7	2.1	2.8	5.0 ML			
22.	Боровое	СКМ	+iP	05-03-28.5	0.5	0.019	0.077	0.352	6.2	15.01	61	-3.7
			Pмах	30.4	0.5			0.352	6.2			
			iS	06-03.1								
22.	Пулково	ВЭГ	P	05-03-37.5						15.73	325	-2.0
			Pмах	40.0	1.6			0.9	6.2			
			e	06-30								
24.	Львов	СКД	eP	05-03-38						15.89	285	-3.6
			i	03-45								
			e	03-52								
			e	03-54								
			e	06-26								
			e	06-52								
			LM	11-16	10	1.6			4.4 MLH			
			LM		13			1.9	4.4 MLV			
			LM		12		2.0		4,5 MLH			

I	2	3	4	5	6	7	8	9	I0	II	I2	I3
27.	Самарканд	СК	eP	05-03-39.6						15.4^x		
			i	03-41								
			i	03-47.2								
			e	06-29.8								
			ML	12-55.0	9.0	0.8	1.7	1.7	4.6 MLH			
									4.5 MLV			
28.	Ташкент	СКМ	+iP	05-03-46.0						16.49	105	-3.3
			P	03-53.5								
			Pmax	54.0	1.5			1.0	6.3			
		СК	Pmax	54.0	2.0	1.0	1.5	2.5	6.6			
		СКМВ	e	06-06								
		"	e	07-07								
		"	e	09-02								
		СК	ML	12-12.0	12		3.6	2.4	4.7 MLH			
									4.6 MLV			
29.	Ужгород	СКМВ	+iP	05-03-54.0						17.12	281	-3.1
			Pmax	04-00	1.1			0.1	5.4			
					(0.8)			(0.3)				
			i	04-09								
			i	04-18								
			i	04-30								
			i	04-43								
			i	05- 04								
		СКД	i	06-22								
30.	Душанбе	СК	+iP	05-04-05						17.73	114	0.1
31.	Наманган	СК	eP	05-04-10.2						17.8^x		
32.	Гарм	СКМВ	iP	05-04-13.2						18.42	110	-0.3
			Pmax	13.2	0.9			0.05	5.1			
			Pmax	18	1.4			0.65	6.0			
			e	04-25.8								
			e	10-52.2								
			e	12-51								
			e	14-15								
33.	Андижан	СКМВ	+eP	05-04-16.1						18.78	103	-1.8
		"	Pmax	21.5	1.1			1.1	6.3			
		СК	Pmax	21.5	1.6			1.5	6.3			
			e	05-12								
			e	08-54								
			ML	16-10.0	8.0	3.0	3.0	2.0	5.1 MLH			
									4.8 MLV			

I	2	3	4	5	6	7	8	9	I0	II	I2	I3
34.	Фрунзе	СКМЗ	+eP	05-04-22.2						19.31	95	-1.9
			e	04-26.4								
			Pmax	28.0	1.0			0.33	5.8			
			i	04-40								
			e	04-56.2								
			e	08-12.4								
			e	08-24.6								
			e	12-24.5								
		СКД	LM	16-00.6	9.0	2.0			4.7			
35.	Талгар	СКМЗ	iP	05-04-41.7	1.0	0.35	0.34	+0.75				
			iL	11-10.5	7.2	0.46						
			LM	12	10	0.7	0.84	0.9				
34.	А[illegible]	СКМЗ	+iP	05-04-42.8						21.04	344	0.1
		e	Pmax	45.6	1.0			0.85	6.1			
		СКД	Pmax	45.6	1.2	1.3	1.2	2.5	6.5			
		СКМЗ	i	04-47								
			iS	08-29.4								-4.1
			iS	08-35								
			i	08-27								
			e	08-52.7								
		СКД	LM	14-30	10	1.3		1.6	4.6 ML 4.7 ML			
		СД-1	LM		9.0			1.9	4.8 MLV			
35.	Семипалатинск	СКМЗ	+iP	05-04-43.7						21.12	71	0.1
36.	Нарын	СКМ	+iP	05-04-49.2						20.73	98	9.5
			e	05-51.4								
[illegible].	Талгар	СКМЗ	P	05-04-41.7	1.0	0.35	0.34	+0.75		20.5x		
			e iL	11-10.5	7.2	0.46						
			LM	12	10	0.7	0.84	0.9				
37.	Пржевальск	СКМЗ	eP	05-04-54.0						22.00	93	1.4
			Pmax	56.0	1.0	0.08	0.1	0.32	5.7			
		СК	LM	17-40	10	1.5	2.0	2.0	4.8 ML			
38.	Новосибирск	СКМЗ	+iP	05-05-02.5						22.85	59	1.4
			Pmax	04.3	1.1	0.12	0.236	0.376	5.8			
			i	06-06.3								
			e	09-13								
			Smax	20.0	1.7	0.068	0.116		4.5			
		СД-1	LM	16-24	12	0.8	1.0	1.3	4.5 ML			

17.X.78 (05-00)

I	2	3	4	5	6	7	8	9	I0	II	I2	I3
39.	Ельцовка	СКМ3	+iP	05-05-19.0						24.63	63	0.9
			Pмах	19.0	0.7	+0.112	+0.290	0.484	6.2			
			e S	09-39								1.1
40.	Норильск	СКМ3	+iP	05-06-00.5						29.03	27	1.9
			Pмах		1.0			0.102	5.6			
			i	06-14								
			i	06-40								
			i	07-14								
			i	07-32								
			i	08-03								
			i	08-51								
			i	09-14								
			i	09-27								
41.	Хейс	СКМ3	+iP	05-06-34.8						32.98	3	1.5
			Pмах	35.8	1.3			0.1	5.6			
			i	06-52								
			i	07-37								
			i	07-50								
			i	08-18								
			i	09-18								
			i	12-07.8								
			e	13-44								
42.	Монды	СКМ3	+iP	05-06-42.7						33.76	63	2.6
			Pмах	43.8	1.0			0.21				
			e S	15-51								
43.	Закаменск	СКМ3	+iP	05-06-57.7						35.51	64	2.3
			Pмах		1.1			0.06	5.4			
			e	08-12.1								
		СКД	M L	23-55	11.5			0.64	4.6 MLV			
44.	Иркутск	СКМ3	+iP	05-06-57.4						35.56	61	1.[illegible]
			Pмах	56.7	1.0			0.192	5.9			
					8.0	0.097						
		СКД	e Le	23-30								
		СКД	LM	24-[illegible]	9.0			0.43	4.5 MLV			
45.	Бодайбо	СКМ3	+ P	05-07-30						39.50	50	1.3
			Pмах	31.0	0.8	0.142	0.34	0.57	6.5			

??

I	2	3	4	5	6	7	8	9	I0	II	I2	I3
46.	Тикси	СКМ3	+eP	05-07-56.0						[illegible]-61	27	1.9
			Pmax	57.5	1.0			0.084	5.6			
			e	08-05.5								
			e	09-38.5								
47.	Якутск	СКМ3	+iP	05-08-19.9						45.68	40	0.9
			Pmax	20.4	0.8			0.027	5.3			
				10-16.3								
48.	Сеймчан	СКМ3	+iP	05-09-27.4						54.48	33	1.6
			Pmax	28.4	1.0			0.161	6.1			
			e	10-03								
			i	10-30								
		СКД	i	16-15.4								
49.	Магадан	СКМ3	-eP	05-09-35						55.47	36	1.[illegible]
			Pmax	36.0	0.6			0.04	5.7			
			e	09-57								
			e	13-56								
50.	Юж.Саха-линск	СКМ3	+eP	05-10-06.3						59.91	52	1.4
			Pmax	07.2	0.9		0.08	0.16	6.1			
			e	10-09								
			e	10-51.8								
		ШО	LZ	40-06	16		0.9	0.7	5.0 MLH 4.8 MLV			
		СКД	LM	40-09	16	0.5	1.0	1.0	5.1 MLH 5.0 MLV			

18 (рес.) декабря 1978 (Азгир 1Х) (08-00)

Западн.Казахстан
ЕССН: 0-07-59-56,0
φ =47,92 N
λ= 48,10E
h =0 км
MPV(A) =6.1 (22 ст) MPV(B)= -6,1 (4ст)
скм cr
MLH(B)=5,1 (8ст)
MLH (C)=5,I
MLV (C)=4,9 (4ст)
Запад.Казах.(28-336)-N рег

USC: H=07-59-56,0
φ=47,78 N
λ=48,14E h=0км
MB=5,9 MS=5,2

№№	Станция	Прибор	Фаза	Время	T сек	A NS	A EW	A Z	Мад	Δ°	Az°	Res
	2	3	4	5	6	7	8	9	10	11	12	13
	Махачкала	СК	+iP	08-01-15.0						4.96	185	1.3
			Pmax	19.0	1.4			1.0				
			i	02-37								
			e	02-55								
			i	03-34								
			Mλ	06-00.0	8.0	17.0	7.0	15.0	4.8 4.7			
2.	Пятигорск	СКМЗ	iP	08-01-18.2						5.24	223	0.8
			i	01-38								
			i	01-45								
			i	03-01								
			i	04-10								
3.	Бакуриани	СКД	+iP	08-01-41.0						6.99	209	-1.1
			Pmax		2.0			0.94				
			i	02-24								
			i	02-33								
			i	02-39								
			i	03-03								
			Mλ		11	18.4			4.9			
4.	Кировабад	СКМЗ	iP	08-01-46.0						7.29	190	-0.3
			i	02-21								
			Mλ		6.0	2.0	3.0		4.5			
5.	Сочи	СКМЗ	+iP	08-01-47.5						7.29	236	1.2

I	2	3	4	5	6	7	8	9	10	11	12	13
6.	Баку	СК	iP	08-01-53.0						7.64	169	1.7
			Pmax		0.1			5.4				
			i	01-59								
			i	02-28								
			iM		2.0	15.0	128.0		6.5			
7.	Ленинакан		+iP	08-01-54.0						7.77	204	0.9
			e	04-18								
8.	Ереван		P	08-01-58.2						8.16	199	-0.2
			e	03-47.4								
			i	04-[illegible].8								
9.	Горис	ВЭГ	+iP	08-02-01.8						8.50	189	-1.5
			Pmax		1.2			0.6				
			i	02-16.2								
			i	02-32.4								
			i	02-44.4								
			i	04-00.6								
			e	05-07.6								
			i	05-46								
			iM		6.0	3.8	3.7		4.7			
10.	Ст. № 1 (Михнево)	СКМЗ	iP	08-02-15.8	0.8			1.5		9.1x		
		СКМ	Pmax	16.0	0.8	1.45	1.2	1.74				
		СК	iS	16	0.8			2.7				
		СКМ	iS	04-02	1.6	6.6	7.8					
		СК	iM	07-34	8.0	12.5	15.5	13.0				
11.	Симферополь	СКД	-iP	08-02-25						10.10	258	-0.3
			Pmax		2.0			1.2				
			iS	04-19								-1.6
			iM	09-00	10	3.9		2.5	4.5 4.3			
		СД-1	iM		10			4.8	4.6			
12.	Москва		+iP	08-02-26						10.16	324	0.0
			Pmax	29.0	1.5			0.15				
			e	02-36								
			e	03-08								
			iM	08-07.9	9.0			10.1	5.0			

I	2	3	4	5	6	7	8	9	I0	II	I2	I3
13.	Обнинск	СКМЗ	−iP	08-02-24.3						10.17	319	−1.9
			Pmax	27.0	0.8			0.23				
			e	05-20								
		ПЕО	iM	07-40.0	10	6.6	8.1	8.3	4.9 MLH 4.8 MLV			
		СК	iM		8.0		7.4	10.0	4.9 MLH 5.0 MLV			
		СКД	iM		8.0			1070	5.0			
14.	Арти	СКМЗ	+eP	08-02-28.7						10.65	33	−4.1
			Pmax		1.0			0.05				
			e	02-31.2								
			e	02-33.2								
			e	02-47.2								
			e	02-59								
			e	03-18								
			e	04-20.2								
			e	04-26								
			e	04-42								
			iM	08-04	12	7.0	11.0		5.0 MLH			
			iM		11		38.8		5.5 MLH			
15.	Свердловск	СКМЗ	+iP	08-02-43.5						11.74	35	−4.[illegible]
			Pmax	47.5	1.5		1.	1.35				
			e	04-48								
16.	Кишенев	СК	−eP	08-03-02						13.08	273	−3.[illegible]
			i	03-03								
		СКД	i	03-04								
			i	04-37								
			i	04-44								
			i	05-23								
			i	05-28								
		СКД	iM	09-40								
17.	Боровое	СКМЗ	+iP	08-03-26.5	0.5			0.550		14.3x		
18.	Пулково	СКД	eP	08-03-37.0						15.78	325	−3.9
			Pmax	38.0	2.0			3.0				
			i	03-46								
			e	04-07								
			e	04-18								
			eS	06-27								−9.8
			e	06-51								
			e	07-35								
			e	08-24								
		СКД	iM	11-23.0	10	5.3	3.0	7.0	5.0 5.1			

1	2	3	4	5	6	7	8	9	10	11	12	13
19.	Самарканд	СК	+iP	08-03-38.2						15.91	114	-4.5
			i	03-42.2								
			i	03-46.8								
			e	06-58.4								
		СК	iM	12-52.0	9.5			5.5	5.0	MLV		
		"	iM		9.0	3.0	6.5		5.1	MLH		
20.	Львов	СКД	+iP	08-03-39.7						15.94	285	-3.
			i	03-49								
			i	04-01								
			eS	06-40								-0.7
			i	06-55								
			i	06-58								
			i	07-42								
			iM	11-51	9.0		6.4	6.4	5.1	ML		
21.	Ужгород	СКМЗ	eP	08-03-56.0						17.17	282	-2.7
			e	04-01								
			Pmax		0.8			0.26				
			Pmax		1.1			0.65				
			e	04-07								
			e	04-16								
			e	04-26								
			e	04-32								
			i	04-50								
			e	04-56								
			i	05-05								
			i	05-50								
			i	05-58								
			e	06-30								
			i	06-55								
			eS	07-03								-6.1
22.	Душанбе	СК	+iP	08-04-04.0						17.68	114	-1.1
			eS	07-22								1.2
			iM		8.0	6.0		5.0	5.2	MLH		
									5.1	MLV		

I	2	3	4	5	6	7	8	9	IO	II	I2	I3
23.	Гарм	СКМЗ	+iP	08-04-12.9						18.37	110	-0.8
			Pmax		1.6			1.45				
			e	07-45.3								
				11-05								
24.	Кулеб	СК	+iP	08-04-16.8						18.72	114	-1.1
		"	Pmax	21.3	1.2			2.8				
		"	i	05-05.6								
		"	iS	07-49.3								5.0
		СК	iM	08-15.0	9.0			4.3	5.0 МLV			
25.	Андижан	СКМ	+iP	08-04-16.5						18.73	103	-1.6
		"	Pmax		1.6			3.9				
		СК	Pmax	21.5	1.6			4.0				
			e	05-23								
			e	07-25								
			iM	16-15.0	8.0	10.5	12.6	12.3	5.7 MLH			
									5.6 MLV			
26.	Фрунзе	СКМЗ	+eP	08-04-22.8						19.26	95	-1.6
			Pmax	30.7	1.4			0.47				
			Pmax		1.5			0.8				
			e	04-47.4								
			e	04-56.2								
			i	05-09.6								
			i	05-11.2								
			e	08-35.2								
			e	09-27								
		СКД	iM	16-13.0	9.0	7.6		3.7	5.3 MLH			
									5.0 MLV			
27.	Хорог	СК	iP	08-04-36.0						20.06	112	2,5
			Pmax		3.0			2.0	6.1			
			i	08-23.0								8.9
			i	08-59								
			i	09-07								
			i	11-34								
			i	12-18								
			iM	14-41.0	11.0	1.0	0.4	2.0	4.4 MLH			
									4.7 MLV			

I	2	3	4	5	6	7	8	9	10	II	I2	I3
28.	Нарын	СКМ3	eP	08-04-35.9						20.68	98	-4.1
			Pmax		1.6			1.74	6.2			
			eS	08-34.6								7.8
29.	Талгар	СКМ3	+iP	08-04-42.0						20.85	92	0.3
		"	Pmax	43.0	1.3			0.82	6.0			
		СКМ	Pmax		6.0			1.1	5.4			
				04-57								
				08-35								
				15-14								
30.	Апатиты	СКМ3	+iP	08-04-42.8						21.08	344	-1.1
		"	Pmax	46.0	1.2			1.9	6.4			
		СКД	Pmax		1.8			3.9	6.5			
		"	i	04-53.6								
		"	i	05-03								
		"	i	05-30								
		"	e	08-35								0.7
		СКД	iM	14-15.0	11	7.5	4.5	10.0	5.4 5.4	MLH MLV		
		СД-1	M	14-15	11			8.5	5.3	MLV		
31.	Семипалатинск	СКМ3	+iP	08-04-43.5						21.08	71	-0.5
			eS	08-30.7								
32.	Пржевальск	СКМ3	+iP	08-04-54.0						21.96	93	1.0
		"	Pmax		1.0			0.64	6.0			
		СК	Pmax		1.6			1.5	6.1			
			e	05-01								
			e	09-16								
			iM		9.0			7.0	5.4	MLV		
33.	Новосибирск	СКМ3	+iP	08-05-02.0						22.83	59	0.5
			Pmax		1.6			1.4	6.2			
			iS	09-04								
		СД-1	iM	16-26.0	12.8	1.4	3.2	3.6	4.9 5.0	MLH MLV		

I	2	3	4	5	6	7	8	9	I0	II	I2	I3
34.	Ельцовка	СКМ3	+iP	08-05-19.0						34.60	63	0
			Pmax		2.0			1.5	6.2			
			eS	09-41								
35.	Хейс	СКМ3	+iP	08-06-35.0						33.00	2	0.7
			Pmax	36.0	1.4			0.2	5.8			
			i	06-51								
			i	07-35								
			e	07-50								
			i	08-13								
			i	09-18								
			i	09-57								
			i	10-46								
		СКД	iM	28-04.0	19	2.3	9.6	4.4	5.2 MLV 5.4 MLH			
36.	Монды	СКМ	+iP	08-06-42.0						33.73	63	1.1
			Pmax		1.6			0.65	6.3			
37.	Закаменск	СКМ3	+iP	08-06-57.3						35.48	64	1.4
			Pmax	58.6	1.4			0.17	5.8			
			e	08-11.9								
		СКД	iM	23-38	14			1.6	4.9 MLV			
38.	Иркутск	СКМ3	+iP	08-06-56.5						35.53	61	0.2
		"	Pmax		1.3			0.19	5.8			
		СКД	Pmax		2.0			0.43	6.0			
			e	07-01.8								
			e	07-13.8								
			e	07-20								
			e	07-48								
			e	08-21.8								
		СКД	iM	23-40	13			1.71	4.9 MLV			
		"	iM		6.0	0.64			4.9 MLH			
		"	iM		14		1.46		4.8 MLH			
39.	Бодайбо	СКМВ	+iP	08-07-30						39.55	50	0.1
			Pmax		1.0			0.41	6.3			

I	2	3	4	5	6	7	8	9	10	11	12	13
40.	Тикси	СКМ	+iP	08-07-55.5						42.61	27	0.6
		СКД	Pmax	56.5	2.0			0.3	5.8			
		СКМ	Pmax	56.5	1.1			0.18	5.9			
		"	e	09 -39.5								
		СКД	LM	29-03	16			1.3	4.9	MLV		
			LM		16	0.6			4.5	MLH		
			LM		18		1.8		5.0	MLH		
41.	Тупик	СКМЗ	+iP	08-08-05.1						43.67	53	1.4
42.	Якутск	СКМЗ	-iP	08-08-18.5						45.67	40	-1.2
			i	10-13.5								
			Pmax	10-16.0	1.8			0.5	6.2			
43.	Ст. № 2	СКМ	+iP	08-09-13.0	2.0	0.136	0.256	0.53		52.0[x]		
			Pmax					0.715				
			i	10-21	1.4			0.126				
			e	14-03								
			e	32-15								
			e	34-18								
44.	Сеймчан	СКМЗ	-iP	08-09-27.6						54.42	33	1.1
			Pmax	28.4	1.7			0.46	6.3			
			e	09-35.8								
45.	Магадан 1	СКМЗ	-iP	08-09-34.5						55.46	36	0.4
			PP	35.3								0.8
			Pmax	36.5	1.0			0.08	5.8			
			e	09-56								
46.	Иультин	СКМЗ	-iP	08-09-54						59.31	18	-[illegible].2
			Pmax	57.0	1.6			0.06	5.4			
			Pmax	10-02	1.0			0.29	6.3			
			i	10-09								
			i	10-29								
			i	10-33								
			i	10-41								
			e	18-42								
			e	19-00								
		СКД	ML	43-00	14	1.0		1.3	5.1	MLV		
47.	Юж.Сахалинск	СКМЗ	+ P	08-10-06						59.89	52	0.5
			Pmax	07.1	1.1			0.27	6.2			
			ePP	10-10.7								
			e	10-17								
			e	10-33								
			e	10-52								
			e	21-30								
			e	33-36								

I8.XII.78 Азгир-IX — -235-
(08-00)

Дополнение из с/бюл. с/карточек

I	2	3	4	5	6	7	8	9	I0	II	I2	I3
48.	Зугдиди	СК	+iP	08-0I-44.0						6.8^{x}		
49.	Абастумани	СКМЗ	+iP	08-0I-45.0						6.9^{x}		
			eS	02-20.0	0.5	I.0						
50.	Алушта	СХ	iP	08-02-22.8								
			Pmax	23.8	0.6			0.I0				
			iPP	02-33								
			e	04-II								
		СК	e	04-44								
			eL	06-56								
			LM	08.6	I0			I.0	4.2MLV			
5I.	Ялта	СХ	P	08-02-26.0						9.8^{x}		
			Pmax	27.0	0.5			I.4				
			Pmax	27.0	0.5	0.5	0.5					
			S	04-20.2								
			Smax	23.0	0.9	0.4						
			Smax	24.4	0.75		0.3					
52.	Минск	СК	eP	08-03-I6						I3.5^{x}		
			Pmax	20.0	2.0	I.4I	5.6	2.4				
			eS	05-49								
			eLR	08.4								
		СД-I	LM	09-5I	I2	4.3		6.3				
		СК	LM	I0-08	I0		8.8					
		СК	LM	I0-I0	8.0	5.0		5.0				
53.	Ташкент	СКМЗ	P	08-03-45.3						I5.3^{x}		
			Pmax	48.3	I.2	0.5	I.0	I.2				
		СК	Pmax		2.0	0.6	I.0	2.5				
			i	53.3								
			iM	54.7	2.0	2.2	3.5	6.5				
			e	07-05								
			e	07-30								
			eL	I0-II								
		СД-I	LM	I2-I0	I3			II.3	5.3 MLV			
		СКД	LM		I2		I2		5.4 MLH			
		СК	LM		II		II	8.3	5.2 MLH			
					9	5.5			5.2 MLH			
54.	Наманган	СК	+iP	08-04-09.2	I.4			2.6		I7.7^{x}		

1,c

I8.XП.78 Азгир-IX
(08-00)

I	2	3	4	5	6	7	8	9	I0	II	I2	I3
55.	Фергана	СК	+eP	08-04-I3.9	2.3			2.0		I8.I^{x}		
			eS	07-47.7								
			L	I0								
			LM	I3-57.2	I0.7			I7.2				
56.	Мургаб	СК	iP	08-04-46.0	I.0	0.7	I.0	I.0		20.9^{x}		
			eS	08-42.0								
57.	Усть Элегест	СКМЗ	+iP	08-06-05.2	I.3	0.02	0.08	0.2	6.6	29.2^{x}		
			iS	17-40.2								

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(Jan 1979)

17 января 1979 (Азгир УН) - Западный Казахстан Астраханская обл.

(08-00)

УСС: H=07-59-55,8
φ=47,96 N
λ=48,14 E   h =0км
MB=6,0   MS=4,6

ЕССН: H-07-59-54,6
φ°=47,93 N
λ°=48,06 E
h =0 км
MPV скм (A)=5,9 (по 20ст)
Ml H(B)=4,8 (по 7 ст)
Ml H(C) =4,8 (по 9 ст)

Западный Казахстан (регион № 29-336)

№ пп	Станция	Приб.	Фаза	Время	T сек	A μ NS	A μ EW	A μ Z	Mag	Δ°	Az°	Res
1	2	3	4	5	6	7	8	9	10	11	12	13
1.Пятигорск	СКМ3	iP	08-01-17.6	1,0			2,9		5,23	283	1.7
		Pmax	01-28								
		i	01-40								
		i	01-46								
		M	02-02								
2.Бакуриани	СКМ3	eP	08-01-42.0						6.99	209	1.3
		i	02-22								
		i	02-30								
3.Зугдиди	СВК	+iP	08-01-43						6.8^x		
4.Абастумани	СКМ	+iP	08-01-45						6.9^x		
5.Сочи	СКМ3	+iP	08-01-46.0						7.28	236	1.3
		i	01-48								
		i	01-52								
		i	02-18								
		i	02-23								
		i	02-27								
		Mlr	05-15.0	14.0			3.8	4.1			
6.Кировабад	СКМ3	iP	08-01-46.0						7.30	190	0.9
		i	01-57								
		i	02-12								
		i	02-28								
		i	03-05								
7.Степанован	СКД	+iP	08-01-47.0	1.5			1.5		7.0^x		
		iS	59.8								
		i	02-06.2								
		i	26.6								
		i	45.8	2.0			2.5				
		iM	08-05	12			3.0				

1	2	3	4	5	6	7	8	9	10	11	12	13
8. Ленина-кан		СКД	+iP	08-01-54.0						7.77	204	2.3
			i	02-32								
			eS	03-12								-9.5
			e	03-52								
			LM	08-16.2	12			2.5	4.1			
9. Ереван		СК	+iP	08-01-57.0						8.16	199	-0.1
		СКМЗ	i	02-19								
		СК	(S)	02-44								
			eML	04-41 06	8,0	I,0	I,0	I,0	4,3			
10. Горис		ВЭГ	+iP	08-02-02						8.51	189	0.0
			Pmax		1.6			1.26				
			i	02-15								
		СК	i	02-23.6								
			e	05-18								
			ML	08-48,6	10.0	1.0	0.8	0.8	3.9 ML 3.7 MH			
11. Ст. № 1 (Михнево)		СКМ	+iP	08-02-13.8	0.5			0.07		8.9x		
12. Алушта		СХ	iP	08-02-21.5						9.5x		
			Pmax	22.7	0.5			0.8				
			i	02-32								
			i	02-41.5								
			eS	04-08								
			Smax	09.5	1.0	0.72						
13. Симферополь		СКД СХ	eP	08-02-22.1						10.08	257	-1.5
			eP Pmax	22,8 25,0	0.4			0.5				
		СКД	eS	04-18								
		СКД	ML	07-31	17			1.0	3.7			
		СД-1	MN	07-34	16			1.0	3.7			
14. Москва		СХ	+P	08-02-23						10.13	324	-1.3
			e	03-11								
15. Ялта		СХ	eP	08-02-24.5						9.6		
			Pmax	25	0.5	0.4	0.4	1.2				
			i	02-44.5								
			S	04-12.5								
			Smax	18.5	0.6	0.3	0.3					
16. Обнинск		СКМЗ	+P	08-02-24.5						10.14	319	0.1
			Pmax		1.0			1.2				
			e	05-14								
		СК	ML	08-08.0	8.0	7.8	9.7	14.0	5.1 ML 5.2 MH			

17.Арти	СКМ СКД	eP	08-02-28.0						10.66	85	-3.5
	СКМ	P_{max}	28.5 29.7	0.9			0.2				
		e	02-30								
		e	02-39								
		e	02-44.5								
		e	03-01.7								
		e	04-22.7								-10.0
		e	04-40.7								
		e	05-22.7								
		e	06-27								
		ML	08-14.0	10	1.0	2.0		4.4 MLH			
				11			3.2	4.4 MLV			
18.Кизил-Арват	СК	eP	08-02-31						10.71	143	-1.3
		eS	03-39								
19.Свердловск	СКМ3	+P	08-02-42.5						11.74	36	-3.8
		e	04-52								
		MLR	08,7	28	I,5	3,0	2,5				
20.Ашхабад	СКМ3	+iP	08-02-54.8						12.49	139	-1.7
		P_{max}	54,8	1.0			0.45				
21.Кишинев	СКД	iP	08-03-02	I,0	I,0	I,0			13.05	273	-1.9
		P_{max}	03.0	1.2			1.4				
		i	03-10								
		i	04-29								
		i	04-50								
		i	05-29								
		i	05-49								
	*	ML	09-37.0	11			2,5	4.5 MLV			
22.Боровое	СКМ	-iP P_{max}	08-03-26.4 32,4	0.4			0.777		14.3ˣ		
23.Пулково	ВЭГ	iP	08-03-36.0						15.75	323	-3.1
	*	P_{max}	40.0	1.3			0.7				
	СКД	P_{max}	38.0	1.3			1.0				
		i	03-44	I,8	I,9	I,7					
		eS	06-26								-8.7
	СД-I	MLR	10-40	15			1.6	4.3 MLV			
		M eMLR	II-38 II-20	I5 8,0	I,3	I,4	I,0 I,5	4,IM MLV			
24.Львов	СКД	eP	08-03-36						15.90	285	-5.3
		i	03-46								
		e	03-57								
		e	06-04								
		ML	11-41.0	10			2.5	4.6 MLV			
25.Самарканд	СК	-P	08-03-39.2						15.3ˣ		
		i	46.8								
		P_{max}	47.4	0.4			2.3				
		ML	13-21.4	9.0	1.0	1.5	1.5				

1	2	3	4	5	6	7	8	9	10	11	12	13
26.Ужгород		СКМЗ	-iP	08-03-55.5						17.14	281	-1.4
			Pmax		1.0			0.5				
			i	04-05								
			i	04-10								
			i	04-14								
			i	04-18								
			i	04-23								
			i	04-28								
			i	04-33								
			i	04-53								
			i	05-03								
			i	05-35								
			i	06-08								
			i	07-00								
			i	09-23								
		СКД	Mλ	12-00.0	12		2.5	3.5	4.6 MLH 4.8 MLV			
27.Душанбе		СК	eP	08-04-04.2						17.71	114	0.1
28.Фергана		СКМ	iP	08-04-04.1						17.3[x]		
		СК	λM	13-								
29. Гарм		СКМЗ	eP	08-04-12.4						18.40	110	-0.3
		"	Pmax	19.3	1.1			0.68				
		СКД	Pmax		2.0			0.44				
30. Куляб		СК	+iP	08-04-16.5						18.75	114	-0.5
			Pmax	04-20.0	1.2			1.3				
			i	05-21								
			e	10-29.7								
31. Андижан		СКМЗ	-eP	08-04-16.2						18.76	103	-0.9
		"	Pmax	20.0	1.6			2.6				
		СК	Pmax		1.6			2.8				
			e	08-31								
		СК	λM	16-17	8.0	1.5	4.5	3.6	5.1 ML 5.0 ML			
32.Фрунзе		СКМЗ	-iP	08-04-21.1						19.29	95	-2.3
			Pmax	26.6	1.0			0.38				
		СКД	e(PP)	04-41.1								
			e	04-53.1								
		СКМ	iS	07-46.5								-9.3
			i	07-48.1								
			i	07-51.1								
			e	07-55.1								
		СК	Mλ	14-23	10			1.5	4.6 Mλ			
		СКД	Mλ	14-25	12			2.0	4.6 Mλ			

1	2	3	4	5	6	7	8	9	10	11	12	13
32.	Талгар	СКМЗ	+ P	08-04-41.0						20.88	92	0.3
			P_m ax	41.3	1.2	0.13	0.2	0.5				
			P_m ax	44.0	1.4			1.5				
33.	Алмаата	СКМЗ	+ P	08-04-41 04-43.7						21.06	344	-1.3
			e i	08-31.8								-0.7
		СКД	λ M	14-24.0	11	2.0	0.5	2.5	4.7 ML 4.8ML			
		СД-1	λ M		10			2.6				
34.	Семипалатинск	СКМЗ	+ P Rmax i	08-04-42.6 43,8 08-34.1	0,8			0,81		21.11	71	-0.3
35.	Пржевальск	СКМЗ	+iP	06-04-53.3						21.99	93	1.4
			P_m ax		1.2			0.4	5.7			
36.	Новосибирск	СКМЗ	+iP	08-05-00,3						22.84	59	0.0
			P_m ax		1.3			0.25	5.5			
37.	Ельцовка	СКМЗ	+iP	08-05-09.4						24.62	63	-8.1
			P_m ax		1.4			0.95	6.1			
38.	Хейс	СКМЗ	+iP	08-06-33.4						32.99	2	0.6
			P_m ax	34.6	1.4			0.12	5.6			
			i PP	06-38								4.6
			i	07-16								
			i	07-48								
			i	08-41								
			i	09-18								
39.	Монды	СКМЗ	+iP	08-06-41.0						33.75	63	1.3
			P_m ax		1.1			0.35	6.2			
40.	Закаменск	СКМЗ	+ P	08-06-56.5						35.50	64	1.8
			P ax	57,5	1.2	0,040	0,074	0.12	5.7			
			e	09-24.6	I,I			0,064	5,4			
			e	11-46.5								
			e	16-43.5								
		СКД	Mλ	23-37.5	18 10,0	0,42		0.74	4.6 MLv			
41.	Иркутск-2	СКМЗ	+eP	08-06-56.3						35.55	61	1.2
			P ax	57,3	1.0 I,2	I,II	0,205	0.33	6.2			
			e	07-12.8								
			e	07-38.5								
		СКД	λ M	23-44	12			0.68	4.6 MLv			
		СКД	λ M	23-44	13		0.5		4.4 MLH			

17.1.79

1	2	3	4	5	6	7	8	9	10	11	12	13
42.	Бодайбо	СКМЗ	+iP	08-07-28.6						39.56	50	-0.1
			Pмах		1.0			0.9	6.6			
43.	Тикси	СКМЗ	eP	08-09-26.5						42.61	27	33.0
			Pмах	39.5	1.2			0.11	5.7			
44.	Якутск	СКМЗ	-P	08-08-18.7						45.68	40	0.3
			Pках	20.0	1.0			0.53				
	—		i	10-14								
45.	Ст. № 2	СКМ	+P	08-09-12.0	1.2	0.061	0.084	0.19		51.8[x]		
			PcP	10-22	1.2			0.008				
46.	Сеймчан	СКМЗ	+iP	08-09-25.9						54.43	33	0.7
			Pмах	27.4	1.0			0.02	5.3			
			Pмах		1.1			0.08	5.7			
			Pмах		1.2			0.11	5.8			
			e	09-47.9								
47.	Магадан-1	СКМЗ	-iP	08-09-33.8						55.47	36	1.0
			Pмах	36	1.0			0.11	5.9			
			i	09-39								
			i	09-56								
			e	10-08								
			e	10-34								
			e	12-07								
48.	Владивосток	СКМЗ	-i	08-10-37.4						56.16	61	59.4
			Pмах		1.1			0.16	6.0			
49.	Иультин	СКМЗ	iP	08-10-00.5						59.31	18	0.7
			Pмах		1.0			0.18	6.1			
			iPP	10-05								
			i	10-19								
			i	10-43								
49.	Юж.-Сахалинск	СКМЗ	+iP	08-10-05						59.90	52	0.8
			Pмах	06.8	1.0			0.28	6.3			5.0
			ePP	10-10								
			e	10-25								
			e	10-44								
			e	12-12.5								
			e	12-17								
			eM	12-18.6	1.1			0.06				
			e	18-39								
			e	21-04								
			e	23-57								
			e	26-56								
			e	28-24								
		СКД	LM	40-08.0	15	0.7	1.5	1.1	5.2 ML 8.1 ML			
50.	Новолазаревская	УСФ	PKKP	08-18-50								
			Pмах	50.5	0.8			0.03				
			e	20-38								

51. Углегорск	СКД	e	08-09-53.3						57.5^{x}
52. Махачкала	СК	+iP	08-01-15.5	0.8	-1.4	-1.1	+4.0		4.8^{x}
		Pmax	18.0	0.8			9.0		
		i	01-22.8						
		e S	02-44						
		e S	02-54						
		Smax	02-58.0	1.4	11	7.0			
		MLR	06-18	8.0	4.5	3.2	4.3 ML		
53. Баку	СК	+iP	08-01-53						7.5^{x}
		e	01-59						
		e	02-40	1.0	5.1	5.0	6.4		
54. Минск	СК	+iP	08-03-16						13.5^{x}
		e LQ	09,5						
		e LR	09,7						
	СД-1	Mi	09-50	12			2.4		
55. Мургаб	СК	iP	08-04-45.0	0.8	-0.3	+0.5	+0.6		20.8^{x}
		e S	08-41						
56. Тикси	СВКМ3	+ P	08-07-54						41.9^{x}
	СКД	+iP	54.5						
	"	Pmax	55.5	1.4			0.2	5.9	
	СВКМ3	Pmax	55.5	1.1			0.21	6.1	
	"	e	08-03						
	"	e	17.5						
	СКД	MLR	28-53	18			0.6	4.5	
				17		0.3	4.3		
57. Петропавловск	СКМ3	e	08-10-23.5						61.8^{x}
		e	12-25						
58. Ст.№ 2 (Кульдур)	СКМ	+ P	08-09-I2,0	I,2	0,05I	0,084	0,I9		$5I,8^{x}$

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14 (july) июля 1979 (Азгир XI) - Западный Казахстан

(05-00)

ЕССН = 04-59-54,2

φ°=49,99N

λ°= 48,10E

h =0км

MPV(A)=5,6 (13ст) MLV(B)=4,1(4ст)

Зап.Казахстан СССР

ЖС:H=04-59-58,2

φ=47°,81N

λ=48°,07E h=0км

MB=5,6

№ пп	Станция	Приб.	Фаза	Время	T сек	A NS	A EW	A Z	Mag	Δ°	Az°	Res
1	2	3	4	5	6	7	8	9	10	11	12	13
1.	Грозный		iP	05-01-13.0				2,0		4.96	200	1.3
			e	01-49		2,3	3,3					
2.	Махачкала	СК	+P	05-01-14.6 (17)		2,9	0,9	2,I		5.04	184	1.8
			eS	02-09	I,2			3,I				-3.7
			LM	07-03	8,0	0,9	I,3	I,5	3,7			
3.	Пятигорск	СКМЗ	eP	05-01-16						5.29	223	-0.3
			i	01-25.5								
			i	01-37.5								
			e	01-41.5								
			i	01-43.5								
4.	Бакуриани	СКМЗ	+iP	05-01-40.0						7.05	209	-1.1
			Pmax		1.0			0.43				
			e	01-41								
			i	02-26								
			i	02-25								
			i	02-32								
			i	02-41								
			ML		12		2.7		4.0			
5.	Зугдиди	СВК	+iP	05-01-43						6.8^x		
			Pmax		0.5			1.0				
			eS	02-21								
			Smax		1.0		2.2					
6.	Абастумани	СКМЗ	+iP	05-01-44.0	0.6			0.44		6.8^x		
			iS	02-17	0.8			0.4				

1 2	3	4	5	6	7	8	9	10	11	12	13
7.Сочи	СКМЗ	-iP	05-01-45.9						7.33	236	0.9
		i	02-25								
		Mλ	05-17.0	12			0.5	3.3			
8.Кировабад	СКМЗ	eP	05-01-45.0						7.36	190	-0.4
		i	01-46								
		i	02-53								
		i	02-11								
9.Шемаха		-iP	05-01-48.5						7.36	176	3.0
		i	В4-45								
		λM	06-50.0	11	2.0			4.0			
10.Ленинакан	СКМЗ	eP	05-01-52						7.83	204	-0.1
		P_{max}		2.0			0.6				
		i	02-32								
		i	03-08								
11.Ереван		-iP	05-01-57.8						8.22	199	0.3
		i	02-10.8								
		i	02-37.2								
12.Горис	ВЭГ	-iP	05-02-01						8.57	189	-61.3
		i	01-08.8								
		i	01-14.8								
		e	04-30.4								
		i	05-04.4								
		e	05-51.8								
13.Ст. № 1 (Михнево)	СКМ	-iP	05-02-14.6	0.4			0.860		9.0^{x}		
14.Алушта	СХ	-iP	05-02-21.0						9.5^{x}		
		P_{max}	22.0	0.6			0.27				
		i	02-28								
		i	02-37.6								
		e	03-32								
		i	03-46.5								
		eS	04-14								
		iS	04-18								
		S_{max}	04-19.5	0.7	0.19						
15.Москва	СХ	+P	05-02-23.0						10.10	324	-0.4
		P_{max}	27.0	1.0			1.1				
		Mλ	08-00	8.0			0.9	4.0Мλ			

1	2	3	4	5	6	7	8	9	10	11	12	13
16.	Симферо-поль	СХ	eP	05-02-23.0						10.12	257	-0.7
			P_N ax		0.4			0.4				
			i	02-37								
			e	04-17								-2.1
			iM	07-28.0	18			0.3	3.1			
		СД	iM	08-08	13			0.4	3.4			
17.	Ялта	СХ	e	05-02-23.8						9.7^x		
			+P	24.1	0.8	0.2	0.2	0.7				
18.	Арти	СКМ3	eP	05-02-27.7						10.60	33	-2.5
			e	02-30.7								
			e	02-42								
			e	02-46.7								
			e	04-18.7								
			e	04-22.7								
			e	04-28.7								
			e	04-46.7								
			e	05-02								
			iM	08-19.0	10	0.6	1.0		4.0 MLH			
			iM		12			1.5	4.1 MLV			
19.	Кизил-Арват	СК	eP	05-02-30						10.73	143	-2.1
			e	02-35								
			e	03-25.5								
			e	03-37.5								
20.	Свердловск	СКМ3	+P	05-02-43						11.69	36	-2.0
			P_M ax	46.2	1.2			0.48				
			i	02-48								
			e	02-58								
			e	03-10								
			e	03-26								
			e	03-52								
			e	04-46								
			e	04-57								
			e	05-05								
			e	05-14								
			iM	08-48.0	12	0.5	0.6	1.0	3.8 MLH			
									3.9 MLV			

14.УП.79

1	2	3	4	5	6	7	8	9	10	11	12	13
21.	Ашхабад	СКМ3	P	05-02-54.6						12.51	139	-1.7
			Pmax	54.6	0.5			0.11				
			e	03-07								
			e	03-12.8								
			e	07-45.1								
			e	08-08								
			e	08-44.6								
			LM	14-10.6	8.5			0.9	4.1			
22.	Кишинев	СКД	-iP	05-03-02.0						13.08	272	-1.8
			Pmax	02.5	1.2			0.5				
			i	05-21								
			i	06-58								
		СКД	LM	09-36.0	11			1.1	4.1			
23.	Боровое	СКМ	iP	05-03-25.5						14.95	61	-2.9
			Pmax		0.5			0.110				
24.	Пулково	ВЭГ	-iP	05-03-36.0						15.72	325	-2.3
			Pmax	38.0	1.6			0.42				
			e	03-44								
			i	03-54								
			e S	06-29								
			e	06-52								
		СД-1	LM	11-22.0	9.0	0.6	0.4	0.6	4.1 MLH 4.1 MLV			
[illegible].	Львов	СКД	eP	05-03-37.0						15.9[illegible]	285	-3.9
			i	03-37								
			i	03-45								
			e	07-32								
			e	08-27								
			LM	11-45.0	10			0.9	4.2 MLV			
26.	Самарканд	СК	-iP	05-03-38.5						15.93	114	-2.7
			i	03-41.3								
			i	03-46.3								
		СК	Pmax	46.7	0.5			1.5				
		СК	LM	13-25.3	8.5		0.5	0.7	4.0 MLH 4.2 MLV			

1	2	3	4	5	6	7	8	9	10	11	12	13
27.	Ужгород	СКМ3	eP	05-03-54.5						17.16	281	-2.2
			i	03-57								
			i	04-02								
			i	04-05								
			i	04-11								
			i	04-17								
			i	04-27								
			i	04-33								
			i	04-39.5								
			i	04-53								
			i	06-23								
			i	06-33								
			i	08-00								
			i	08-08								
			i	09-12								
			i	09-24								
			i	10-00								
28.	Душанбе	СК	eP	05-04-02.3						17.71	114	-1.3
			i	13-56.1								
29.	Наманган	СК	eP	05-04-09.2						17.7[x]		
30.	Гарм	СКМ3	eP	05-04-12.1						18.40	111	0.0
			P ах	17.0	2.0			0.35				
31.	Фергана	СКМ3	-iP	05-04-13.5	0.8			0.24		18.0[x]		
			i	04-27.5	1.0			0.3				
		СК	eS	07-43.5								
		"	iM	13-49.5	10			1.4				
32.	Куляб	СК	eP	05-04-15.5						18.74	114	-0.9
			e	04-45.5								
			e	10-29.3								
33.	Андижан	СК	eP	05-04-15.2						18.74	103	-1.2
		"	Pм ах		1.5			0.8				
		СКМ	Pм ах		1.3			0.62				
			e	09-14.2								
			e	10-49.2								
			iM	14-10.0	12	0.7	1.4	1.1	4.5 MLH 4.3 MLV			
			iM	16-16	8.0	0.7	1.6	1.1	4.7 MLH 4.5 MLV			

1 2	3	4	5	6	7	8	9	10	11	12	13
34. Фрунзе	СКМЗ	-eP	05-04-22.0						19.27	95	-0.6
		Pmax	26.5	0.9		0.16					
	СКД	iM	14-27.0	14		0.6	0.6	4.0 MLH 4.0 MLV			
35. Хорог	СК	eP	05-04-33.3						20.08	112	1.3
36. Нарын	СКМ	+iP	05-04-40						20.69	98	1.7
		i	05-39.2								
37. Талгар	СКМЗ	+iP	05-04-41.0	1.0	-0.028	+0.025	+0.07		20.85	92	1.1
		Pmax	44	0.9	0.19	0.16	0.38	5.8			
		e	10-25.1			0.133					
		e	12-08.1	6.0	0.2						
		e	15-16.1	10		0.268					
38. Апатиты	СКМЗ	eP	05-04-41.2						21.01	344	-0.2
	СКД	ML	14-10	13	0.58	0.57	0.96	4.3 MLH 4.3 MLV			
39. Семипалатинск	СКМЗ	+iP	05-04-42.4						21.06	71	0.4
		e	04-54.2								
		e	05-30.1								
		e	07-44.6								
		eS	08-30.7								-1.7
40. Новосибирск	СКМЗ	+iP	05-05-01						22.79	59	1.7
		Pmax		1.2			0.2	5.5			
			09-09								4.6
	СД-1	LM	16-35.0	12	0.3	0.4		4.1 ML			
41. Ельцовка	СКМЗ	+iP	05-05-17.9						24.57	63	1.4
		Pmax		1.0			0.23	5.7			
		eS	09-41								5.7
42. Хейс	СКМЗ	+eP	05-06-34						32.94	2	2.1
		Pmax	35.0	1.4			0.09	5.5			
		i	07-46								
		i	07-48								
43. Закаменск	СКМЗ	+iP	05-06-55.8						35.45	64	2.0
		Pmax		1.0			0.04	5.3			
44. Бодайбо	СКМЗ	+iP	05-07-28.5						39.50	50	0.8
		Pmax		0.3			0.26	6.6			
45. Тикси	СКМЗ	+iP	05-07-54.0						42.55	27	1.5
		Pmax	55.5	1.1			0.05	5.4			
		e	09-29.5								

1	2	3	4	5	6	7	8	9	10	11	12	13
46.	Якутск	СКМ3	eP	05-08-12.2						45.62	40	-3.2
			Pmax	20.2	1.0			0.08	5.7			
			i	10-14.2								
			v	12-46.2								
47.	Сеймчан	СКМ3	+iP	05-09-25.9						54.37	33	1.6
			Pmax	26.9	1.0			0.09	5.8			
48.	Магадан1	СКМ3	- eP	05-09-34.8						55,91	36	2.9
			Pmax	35.0	1.0			0.04	5.5			
			e	10-17								
			e	11-13								
49.	Иультин	СКМ3	+ P	05-09-59.6						59.25	18	0.7
			e	10-39								
50.	Юж.Сахалинск	СКМ3	+ iP	05-07-01.4						59.85	52	-182.0
			e	07-12.6								
			e	07-46								
			e	07-48								
51.	Баку	СК	eP	05-01-51.0						7.3^x		
			e	01-57								
			e	02-26								
			S	02-35								
			Smax	03-03.0	I.6	2.5	I.9					
52.	Минск	СК	eP	05-03-I5						13.5^x		
			e	09-34								
			eS	09-53								
			SSS	12-33								
			2SSS	13-57								
53.	Мургаб	СК	iP	05-04-44.0						20.7^x		
			eS	08-4I								
54.	Новосибирск	СКМ3	+iP	05-05-00,8						22.4^x		
			Pmax	01,5	I,2	0.066	0.132	0.206	5.6			
			i	08,5								
			pP	22,2								
			iS	09-08,9								
			Smax	39,2	I.4	0.015	0,044		4,7			
			i(SS)	13-37,2								
		СД-I	MLq	16-35,2	I2	0.3	0.4		4,2			

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24 октября 1979 (АЗГИР) Западный Казахстан
(06-00)

УЗС: H=05-59-56,7
φ =47°,79N
λ =48°,11E   h =0км
МВ=5,8

ЕССН: 06-59-55,5
φ =47°,96N
λ =48°,10E
h =0
MPV(A)=5,7 (по 15 ст) MLH(D)=4.3
СКМ   СК (5 ст)
МLV(В)=4.4 (по 9 ст)
СК
Зап.Казахстан, СССР

№ пп	Станция	Приб.	Фаза	Время	T сек	A мк NS	A мк EW	A мк Z	Mag	Δ°	Az	Res
1	2	3	4	5	6	7	8	9	10	11	12	13
1.	Грозный		iP	06-01-14.4						4.93	200	1.7
			i	01-40.5								
2.	Махачкала	СКМ3	+iP	06-01-15.5						5.01	185	1.8
			Pмах	19.0	0.5			4.4				
			i	01-26								
			iS	03-13								
			iM	04-50	9.0	0.4	3.0	1.0	3.9 3.5			
3.	Пятигорск	СКМ3	+iP	06-01-17.7						5.26	223	0.4
			Pмах	19.2	1.0			2.3				
			e	01-21.2								
			i	01-27.2								
			i	01-28.2								
			i	01-44								
			i	01-57								
			i	03-12.2								
			i	04-23.2								
4.	Степановская	СКМ3	+iP	06-01-37.4	1.0			0.5		6.4x		
5.	Бакуриани	СКМ3	+iP	06-01-42						7.02	209	-0.1
			Pмах		0.8			0.51				
		СКД	Pмах		0.8			0.66				
			i	02-18								
			iM		10	3.2			4.2			
6.	Зугдиди	СКК	+iP	06-01-44						6.8x		
			Pмах		0.5			3.3				
7.	Абастумани	СКМ3	+iP	06-01-45	0.5			0.8				
			eS	02-16	0.5	0.5						

[illegible]

4. Степанован
i 06-03-07
i 03-41
i 04-08
i 04-20
i max 06-05.5

1	2	3	4	5	6	7	8	9	10	11	12	13
8.	Сочи	СКМ3	+iP	06-01-47.2						7.31	236	1.1
			Pmax	52.0	0.6			1.3				
			i	01-56								
			i	02-37								
			i	02-52.5								
			i	03-02								
		СКД	LM	05-18	13			1.3	3.7			
9.	Кировабад	СКМ3	iP	06-01-46.0						7.32	190	-0.3
			i	03-58								
			e	06-09								
10.	Шемаха		-iP	06-01-46						7.33	176	-0.4
			i	02-25								
			LM	06-03	8.0			4.5	4.4			
11.	Баку	СК	+iP	06-01-53						7.68	169	1.8
			i	01-56								
			i	02-37								
12.	Ленинакан	ВЭГ	eP	06-01-53						7.80	204	0.0
			e	02-34								
13.	Ереван	СК	+iP	06-01-59.5						8.19	199	1.1
			e	05-32.5								
14.	Горис	ВЭГ	+iP	06-02-01.4						8.54	189	-1.8
		СКМ3	i	02-16								
			i	02-31.2								
			e	02-57								
			e	03-40.4								
			e	04-00.2								
15.	Нахичевань	СК	-iP	06-02-10	1.0	[illegible]		1.1		8.7^{x}		
			S	02-54	1.5	3.4						
16.	Ст. № 1	СКМ	+iP	06-02-16	0.7			0.800		9.1^{x}		
17.	Алушта	СХ	-eP	06-02-21.6						9.6^{x}		
			+iP	02-23.2								
			Pmax	23.7	0.5			0.6				
			i	02-29.1								
			i	02-47.7								
			i	03-01								
			e(S)	04-14.7								
		СК	e	05-05								
			e	06-11								
			LM	06-08.9	(9)			0.5	3.7			

24.X.79

1	2	3	4	5	6	7	8	9	10	11	12	13
18.	Симферополь	СК	eP	06-02-24.0						10.11	257	-0.9
			eS	04-20								-0.2
		СКМ	LM	08-20.0	12			0.5	3.5			
19.	Москва		eP	06-02-25.0						10.13	324	-0.1
			e	02-35								
			e	02-55								
			e	05-27								
20.	Ялта	СК	eP	06-02-25.2						9.8[x]		
			iP	25.9	0.5	-0.4	-0.4	+1.2				
			eS	04-19.8								
			eS	04-22.7								
21.	Обнинск	СКМ3	-iP	06-02-25						10.14	319	-0.3
			Pmax	28.0	1.0			0.9				
			e	05-14								
		ПО	LM	07-40.0	10	1.3	1.4	1.7	4.2 4.2			
22.	Арти	СКМ3	eP	06-02-29.6						10.62	33	-2.3
			e	02-42								
			e	02-59.6								
			eS	04-26.6								-6.2
		СКД	iM	08-10	11		2.0		4.2 MLH			
			LM		13			2.4	4.2 MLV			
23.	Кизыл-Арват	СК	eP	06-02-31.5						10.71	143	-1.6
			e	02-36.5								
			i	03-32.5								
			i	04-27.5								
24.	Свердловск	СКМ3	+iP	06-02-45						11.71	36	-1.8
			Pmax	47.5	1.0			0.88				
			i	02-57								
			e	03-04								
			i	03-04								
			i	04-58								
			eS	04-52								-7.3
		СКД	LM	09-52.0	12	1.0	1.2	2.0	4.1 MLH 4.2 MLV			
25.	Ашхабад	СК	P	06-02-54.4						12.49	139	-2.9
			i	04-05								
			Pmax		2.0			0.98				
			i	05-43								
			LM	13-53.5	3.5			1.45	4.7			

1	2	3	4	5	6	7	8	9	10	11	12	13
26.	Кишинев	СКД	−iP	06-03-03.5						13.08	272	−17
			Pmax	04.0	0.6			0.9				
			e	04-52								
			e	05-22.5								
			i	05-28								
			i	06-12								
			i	06-19								
			i	07-12								
		СКМД	iM	09-44.0	11			1.9	4.3			
27.	Минск		eP	06-03-17						14.23	304	−8.3
			e	05-37								
			e	07-18								
		СД-1	iM	09-59	10			1.78	4.4 MLH			
			iM		12		2.2	2.0	4.4 MLH 4.4 MLV			
28.	Боровое	СКМ	−iP	06-03-27.1						14.97	61	−2.9
			Pмах		0.8			0.240				
29.	Пулково	ВЭГ	+iP	06-03-37						15.75	325	−3.0
			Pмах	38.0	0.6			1.1				
			i	03-46								
			i	06-50								
		СКД	iM		9.0	1.2		1.5	4.4 4.5			
30.	Самарканд	СК	eP	06-03-39.4						15.92	114	−3.0
			i	03-42.6								
			i	03 -47.6								
			eS	06-37								−2.9
		СК	iM	12-52.5	10	0.5	1.2	1.5	4.4 MLH 4.4 MLV			
31.	Львов	СКД	eP	06-03-39.5						15.93	285	−2.9
			e	03-48								
			e	04-08.5								
			e	07-02								
			e	06-06.5								
			e	06-53.5								
			iM	11-51.0	8.0			1.5	4.5			
32.	Ташкент	СКМЗ	−iP	06-03-46.6						16.45	105	−2.5
		"	Pмах	48.0	1.2			0.4				
		СК	Pмах		1.5			1.0				
			i	03-51								
			i	03-54								
			i	04-04								
			e	07-55								
		СК	i	09-47				1.4	4.4			
			LM	12-51	11							
			LM		115	[illegible]	[illegible]		4.2			

1	2	3	4	5	6	7	8	9	10	11	12	13
33.	Ужгород	СКМЗ	+ eP	06-03-57.0						17.16	281	-1.1
			i	03-59								
			i	04-02								
			Pmax	03.0	0.9			0.25				
			i	04-04								
			i	04-07								
			i	04-14								
			i	04-20								
			i	04-29								
			i	04-34								
			i	04-53								
			i	05-09								
			i	11-41								
			i	11-56								
34.	Душанбе	СК	+iP	06-04-04.6						17.69	114	-0.2
			iM	14-37.1	9.5		1.5		4.5			
35.	Наманган	СК	-eP	06-04-09.6						17.7^x		
36.	Фергана	СКМЗ	-iP	06-04-14.7	1.0			0.29		18.1^x		
		СК	eS	08-32.2								
			Mi	14-30.2	9.0	2.0			5.0			
37.	Куляб	СКМЗ	+iP	06-04-17.3						18.73	114	-0.3
			Pmax	21.1	1.3			1.0				
			i	04-30								
			e	10-05.6								
38.	Андижан	СКМ	-iP	06-04-16.9						18.74	103	-0.8
		"	Pmax		1.3			1.2				
		СК	Pmax		1.8			1.5				
			e	08-49								
		СК	iM	16-10	8.0	2.0	3.1	2.3	5.0 4.8			
39.	Фрунзе	СКМЗ	-eP	06-04-23.4						19.27	95	-0.6
			Pmax	28.0	0.8			0.13				
			i	04-39.3								
			i	05-11.8								
			eS	07-52.1								-4.0
			e	08-25								
		СКД	iM	16-09	10	1.4			4.5			
40.	Хорог	СК	eP	06-04-33						20.07	112	-0.2

1	2	3	4	5	6	7	8	9	10	11	12	13
49.	Закаменск	СКМЗ	+iP	06-06-57.8						35.47	64	2.5
			Pmax		1.4			0.05	5.3			
			e	09-26								
		СКД	iLR	23-52.4								
50.	Иркутск-2	СКМЗ	eP	06-06-57.8						35.51	61	2.1
			Pmax		1.2			0.1	5.6			
		СКД	iLR	23-40	14			0.26	4.1			
51.	Бодайбо	СКМЗ	+iP	06-07-30.1						39.52	50	0.9
			Pmax		0.8			0.49	6.4			
52.	Тикси	СКМЗ	+iP	06-07-55.8						42.58	27	1.7
			Pmax	56.5	1.0			0.06	5.5			
53.	Сеймчан	СКМЗ	-eP	06-09-27.9						54.40	33	2.1
54.	Магадан-1	СКМЗ	eP	06-09-35.6						55.44	36	2.1
55.	Иультин	СКМЗ	+iP	06-10-01.6						59.28	18	1.1
			Pmax		0.8			0.13	6.1			
			ePP	10-06								4.4
			e	10-18								
56.	Юж.Сахалинск	СКМЗ	+iP	06-10-07						59.87	52	2.1
			Pmax	07.3	0.9		0.05	0.13				
			e	10-12.2								
57.	Новолазаревская	УСФ	PKiKP	06-18-51						121.26	193	1.8
			Pmax	52.0	0.8			0.01				

1	2	3	4	5	6	7	8	9	10	11	12	13
41.	Нарын	СКМЗ	iP	06-04-40.5						20.69)	98	0.9
			Pmax		1.4			0.18	5.3			
		СКД	iM	15-14	10			0.97	4.4			
42.	Талгар	СКМЗ	+iP	06-04-42.0	1.1	-0.035	+0.043	+0.098		20.85	92	0.8
			Pmax	45.0	1.4	0.23	0.29	0.062	4.0			
			e	05-26								
			e	08-49.4	9.0		0.2					
			e	09-32								
			iM	15-00	12			0.6	4.1			
43.	Апатиты	СКМЗ	-iP	06-04-43.3						21.04	344	0.2
			iSP	04-44.2								0.9
			eS	06-36								2.8
		СКД	iM	14-26.0	12	1.9	0.7	1.9	4.7			
									4.7			
		СД-1	iM	14-16.0	10			2.4	4.8			
44.	Семипалатинск	СКМЗ	+iP	06-04-43.8						21.07	71	0.3
			e	05-15.6								
			e	08-23.1								
45.	Пржевальск	СКМЗ	+iP	06-04-55						21.96	93	2.5
			Pmax		1.3			0.32	5.5			
		СК	Pmax		1.6			0.49	5.6			
			e	05-11.5								
			iM	17-30	10			1.2	4.6			
46.	Новосибирск	СКМЗ	+iP	06-05-02.2						22.81	59	1.4
			Pmax		1.6			0.42	5.7			
			eS	09-05								-1.0
		СД-1	iM	19-27	12.	0.35	0.86	1.03	4.4			
									4.4			
47.	Ельцовка	СКМЗ	+iP	06-05-18.9						24.58	63	0.9
			Pmax		1.0			0.35	5.9			
			eS	09-45								8.1
48.	Моды	СКМЗ	+iP	06-06-42						33.72	63	1.7
			Pmax		1.0			0.15	5.6			

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